September 29, 2003

Harry T Stewart, P.E., Director
New Hampshire Department of Environmental Services
Water Division
29 Hazen Drive, Box 95
Concord, New Hampshire 03302-0095

SUBJECT: Notification of Approval of two Hampton/Seabrook Harbor TMDLs

Dear Mr. Stewart:

Thank you for your final submittal of the Hampton/Seabrook Harbor TMDLs for fecal coliform bacteria, which includes the main report (dated August 7, 2003) and supplementary information (Appendix E: Responses to EPA Comments on the Hampton/Seabrook Harbor Bacteria TMDL, dated September 25, 2003). The EPA has determined that TMDLs for two Assessment Units (**NHEST600031004-09-01, NHEST600031004-04-03)** meet the requirements of Section 303(d) of the Clean Water Act (CWA) and of the EPA's implementing regulations (40 CFR Part 130). We, therefore, approve these TMDLs, and have enclosed a copy of our review document.

Approval of these TMDLs is an important step in enabling the State to move forward with on-the-ground measures to improve water quality in the harbor and associated waters. We are pleased that additional data will be collected in the future to evaluate the effectiveness of pollution-control actions, and to determine attainment of water quality standards throughout Hampton/Seabrook Harbor. In particular, we believe that additional information on specific sources (such as marinas, stormdrains and other stormwater sources, and illicit connections) will be necessary to assess attainment in the water segments (known as "assessment units") associated with these TMDLs.

My staff and I congratulate you on producing a comprehensive and informative TMDL report, and look forward to continuing to work with the NH DES to implement requirements under Section 303(d) of the CWA. Please contact me or **Carl DeLoi of my staff if you have any questions or comments on our review.**

Sincerely,

Linda M. Murphy, Director
Office of Ecosystem Protection

Enclosure: EPA Decision Document (EPA Region 1 TMDL Review)

cc: Paul Currier, NH DES
Gregg Comstock, NH DES
Carl DeLoi, EPA
Mel Cote, EPA
Alison Simcox, EPA
Ann Williams, EPA

Total Maximum Daily Load (TMDL) Study for Bacteria in Hampton/Seabrook Harbor

Prepared by:

State of New Hampshire
Department of Environmental Services
Water Division
Watershed Management Bureau

September 2003

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

NHDES-R-WD-03-32

Total Maximum Daily Load (TMDL)
Study for Bacteria in Hampton/Seabrook Harbor

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September 2003

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1. Introduction

a. Background

Section 303(d) of the Clean Water Act (CWA) and EPA's Water Quality Planning Regulations (40 CFR Part 130) require states to develop total maximum daily loads (TMDLs) for water quality limited segments that are not meeting designated uses under technology-based controls for pollution. The TMDL process establishes the allowable loadings of pollutants for a waterbody based on the relationship between pollutant sources and instream water quality conditions, so that states can establish water quality based controls to reduce pollution from both point and non-point sources and restore and maintain the quality of their water resources.

b. Purpose of this study

The purpose of this study is to develop a TMDL for bacteria in Hampton/Seabrook Harbor located in the towns of Hampton, Seabrook, and Hampton Falls, New Hampshire. The goal is to reduce bacteria loads to the harbor so that water quality standards for all the designated uses affected by bacteria pollution are met in all areas of the harbor.

The 1,047 acres of estuarine waters in Hampton/Seabrook Harbor are divided into 14 assessment units for New Hampshire's 305(b) and 303(d) reporting. The 14 assessment units are shown in Figure 1 and are listed in Table 1 and Table 2.

Ten of the 14 assessment units are on New Hampshire's 303(d) list, which is the list of impaired waters that require a TMDL. These assessment units are shown on Table 1**.** Six assessment units within Hampton/Seabrook Harbor are listed because measurements of bacteria concentrations in the assessment unit exceed State surface water quality standards for shellfish consumption. These six assessment units are listed at the top of Table 1. Two of these six assessment units are also listed as impaired for primary contact recreation (e.g., swimming). However, the primary contact recreation impairments are based on reports of discharges of untreated sewage and not actual measured violations of enterococci (the bacteria indicator for swimming in tidal waters). In fact, water quality measurements in the harbor indicate that State standards for swimming are being met.

The four assessment units on the bottom of Table 1 are closed for shellfishing for primarily administrative reasons. Additional information, such as sanitary surveys, are needed to satisfy National Shellfish Sanitation Program (NSSP) protocols before the beds can be classified. In the meantime, shellfishing is prohibited in the unclassified areas. Though officially closed for administrative reasons, these assessment units were included on New Hampshire's 303(d) list because there is some water quality data which suggests that shellfishing water quality standards may not be met in these areas (USGS/DES, 2002).

The last four assessment units in the harbor are listed as impaired by bacteria pollution on New Hampshire's 2002 305(b) list (Table 2). These four assessment units are closed for shellfishing for purely administrative reasons, not because of water quality measurements showing exceedances of standards. The NSSP requires the establishment of safety zones around municipal wastewater treatment plant discharges and the prohibition of shellfishing in the safety zones. The prohibition of shellfishing near wastewater treatment discharges is a precautionary measure to protect harvesters in the event of a wastewater treatment plant failure. These four assessment units have been included in this TMDL because the goal is to meet water quality standards throughout the harbor (these four assessment units plus the 10 units on Table 1 constitute the entire harbor area) and reductions of bacteria loads to the harbor will results in water quality improvements in all assessment units.

It is worth noting that bacteria is not the only pollutant of concern in the Hampton/Seabrook Harbor. All 14 of the assessment units for New Hampshire’s coastal waters are also listed as impaired for fish and shellfish consumption due to polychlorinated biphenyl, dioxin, and mercury concentrations in fish tissue and lobster tomalley. Because of the levels of pollutants found in New Hampshire and neighboring states, the N.H. Department of Health and Human Services has issued state-wide advisories against consumption of certain species of fish and lobster tomalley. The sources of the contaminants in the fish tissue and lobster tomalley are thought to be more regional (e.g., atmospheric deposition) than local.

Table 1: 303(d)-listed waters in Hampton/Seabrook Harbor (2002)

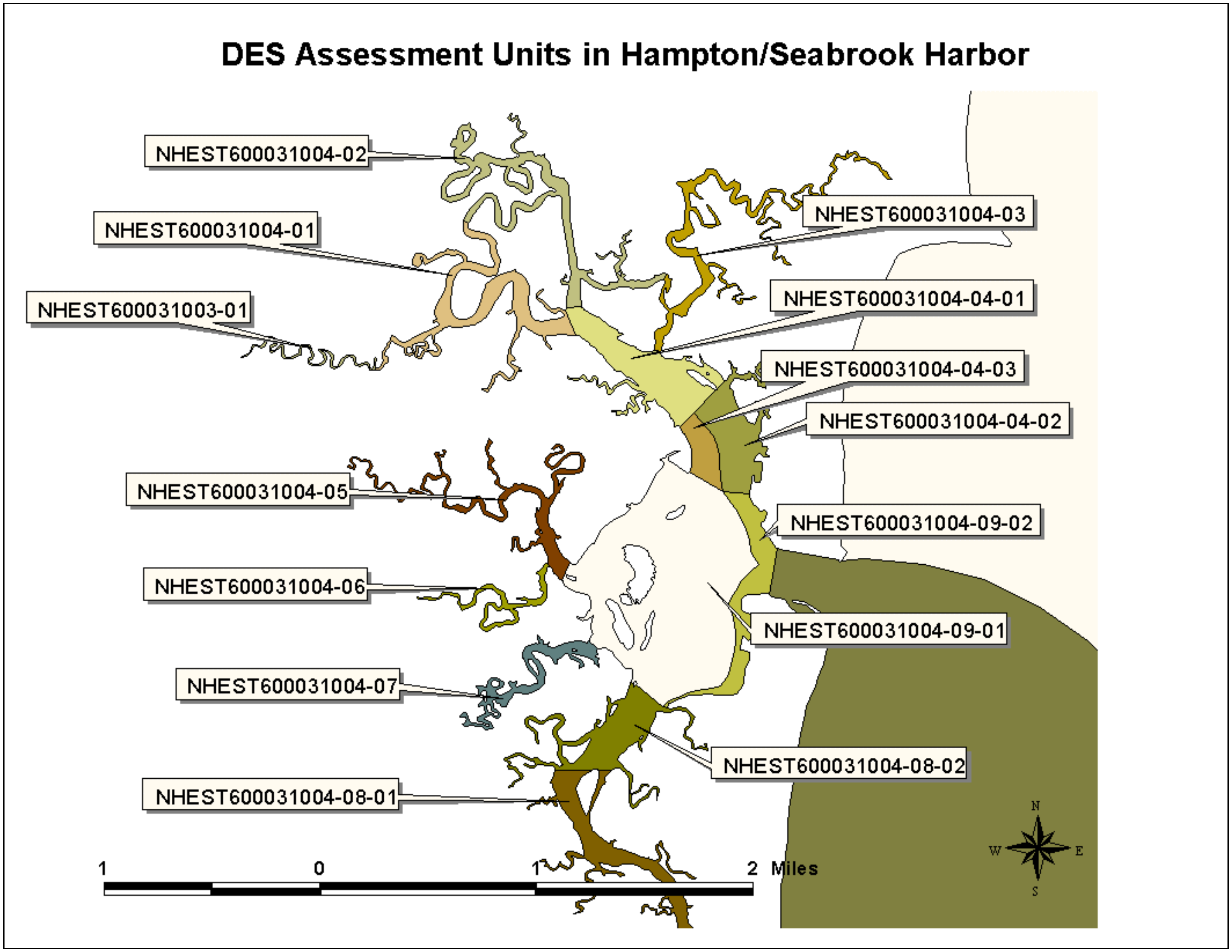
Assessment Unit ID	Name	Acres	Impaired Use	Classification (2001)	Impairment	Source(s)
NHEST600031004-04-02	Hampton River 2	65.60	Shellfishing	Restricted	Total Fecal Coliform	Source Unknown; Sanitary Sewer Overflows (Collection System Failures); Wet Weather Discharges (Point Source and Combination of Stormwater, SSO or CSO)
NHEST600031004-04-03	Hampton River 3	23.04	Shellfishing	Conditionally Approved	Total Fecal Coliform	Source Unknown; Wet Weather Discharges (Point Source and Combination of Stormwater, SSO or CSO)
NHEST600031004-08-01	Blackwater River 1	69.47	Shellfishing	Restricted	Total Fecal Coliform	Source Unknown; Wet Weather Discharges (Point Source and Combination of Stormwater, SSO or CSO)
NHEST600031004-08-02	Blackwater River 2	71.07	Shellfishing	Restricted	Total Fecal Coliform	Source Unknown; Wet Weather Discharges (Point Source and Combination of Stormwater, SSO or CSO)
NHEST600031004-09-01	Hampton/Seabrook Harbor 1	363.88	Shellfishing	Conditionally Approved	Total Fecal Coliform	Source Unknown; Wet Weather Discharges (Point Source and Combination of Stormwater, SSO or CSO)
NHEST600031004-09-02	Hampton/Seabrook Harbor 2	58.23	Shellfishing	Restricted	Total Fecal Coliform	Source Unknown; Sanitary Sewer Overflows (Collection System Failures); Wet Weather Discharges (Point Source and Combination of Stormwater, SSO or CSO)
NHEST600031003-01	Hampton Falls River	7.09	Shellfishing	Prohibited/Unclassified	Total Fecal Coliform	Source Unknown
NHEST600031004-05	Browns River	46.15	Shellfishing	Prohibited/Unclassified	Total Fecal Coliform	Source Unknown
NHEST600031004-06	Hunts Island Creek	15.99	Shellfishing	Prohibited/Unclassified	Total Fecal Coliform	Source Unknown
NHEST600031004-07	Mill Creek	31.35	Shellfishing	Prohibited/Unclassified	Total Fecal Coliform	Source Unknown

*All AU’s are also listed as “Not Supporting” for fish consumption and shellfishing because of state-wide advisories issued by the N.H. Department of Health and Human Services for PCB, dioxin, and Hg contamination. Assessment Units NHEST600031004-04-02 and NHEST600031004-09-02 are also listed as “Not Supporting” for primary contact recreation because of known discharges of untreated sewage to these AU’s, but monitoring data from the harbor does not indicate an impairment for primary contact recreation.

Table 2: 305(b)-listed assessment units in Hampton/Seabrook Harbor

Assessment Unit ID	Name	Acres	Impaired Use	Classification (2001)	Impairment	Source(s)
NHEST600031004-04-01	Hampton River 1	89.06	Shellfishing	Prohibited/Safety Zone	Total Fecal Coliform	Municipal Point Source Discharges
NHEST600031004-03	Tide Mill Creek	55.97	Shellfishing	Prohibited/Safety Zone	Total Fecal Coliform	Municipal Point Source Discharges
NHEST600031004-02	Taylor River	76.81	Shellfishing	Prohibited/Safety Zone	Total Fecal Coliform	Municipal Point Source Discharges
NHEST600031004-01	Hampton Falls River	73.4	Shellfishing	Prohibited/Safety Zone	Total Fecal Coliform	Municipal Point Source Discharges

Figure 1: DES assessment units in Hampton/Seabrook Harbor



2. Problem Statement

a. Waterbody Description

Hampton/Seabrook Harbor is in the coastal drainage watershed of New Hampshire. The land cover in the subwatersheds draining to Hampton/Seabrook Harbor is shown in the following table.

Table 3: Land use categories in the watersheds draining to Hampton/Seabrook Harbor (HUC12 010600031004 and HUC12 010600031003)

Category	Acres	Percent	Comments
Developed Land	8,248	31%	Sum of "Residential-Commercial-Industrial," "Transportation," "Disturbed," and "Cleared/Other Open".
Agriculture	2,049	8%	Sum of "Row Crops," "Fruit Orchards," and "Hay-Rotation-Permanent Pasture".
Forest	11,897	44%	Sum of all forest types
Wetlands	4,714	18%	Sum of "Forested Wetland," "Non-forested Wetland," and "Tidal Wetland".
Total	26,907	100%	Does not include land in the "Open Water" or "Sand Dunes" categories.

Data Source: New Hampshire Land Cover Assessment (2001) UNH Complex Systems Research Center.

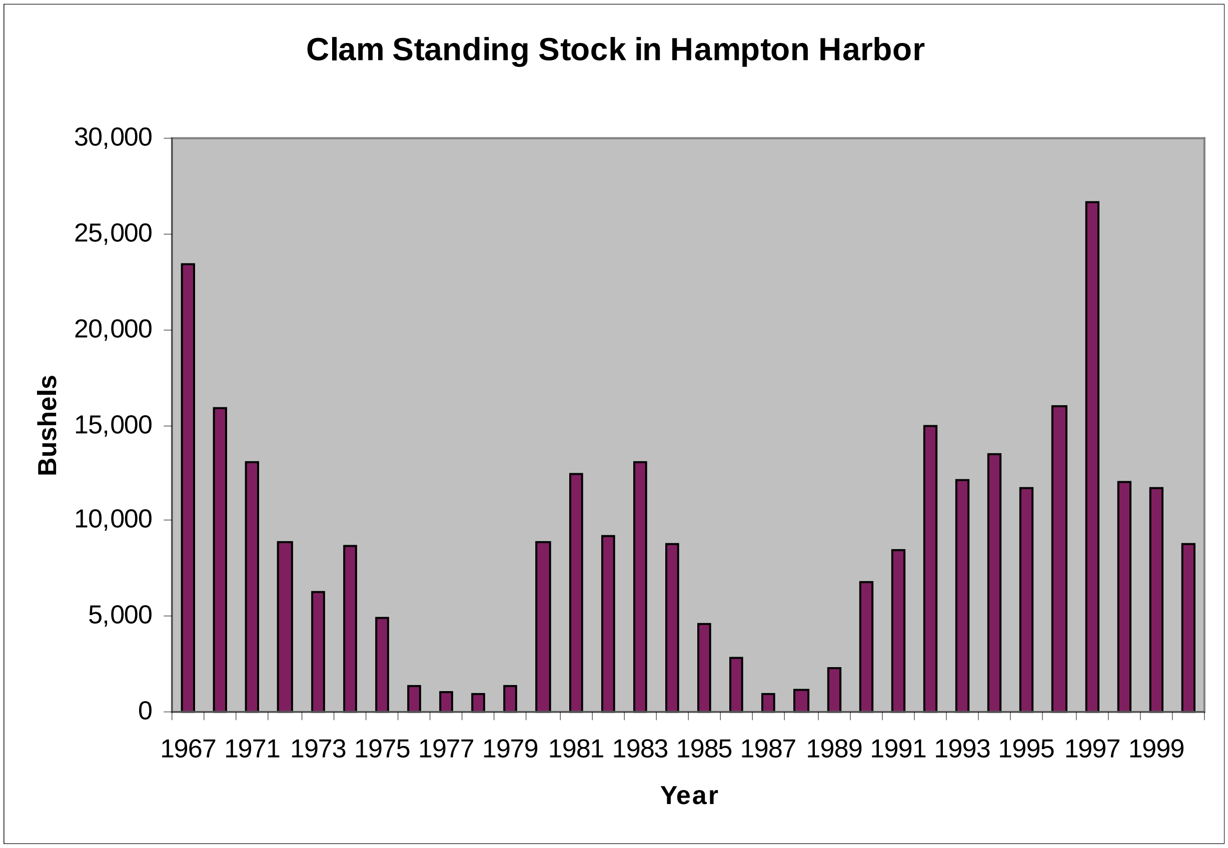
Hampton/Seabrook Harbor experiences strong tidal flushing. Approximately 88 percent of the water in the harbor is exchanged on each tide. The low tide volume of the estuary is 500 million gallons while the high tide volume is 4,200 million gallons (NAI, 1977). Another distinguishing characteristic of the harbor is that it is surrounded on three sides by 5,000 acres of salt marshes. At its eastern edge, the harbor is separated from the ocean by a narrow spit of land that is heavily developed. The northern portion of the spit is the Hampton Beach area. The southern portion is the Seabrook Beach area. There is a small gap in the spit between the towns which is spanned by a bridge and through which the tidal exchange of the estuary occurs. The Seabrook Station nuclear power plant is located on the edge of the salt marshes on the western side of the harbor. Figure 2 is an aerial photograph of the Hampton/Seabrook Harbor region from 2000.

Figure 2: The Hampton/Seabrook Harbor Area

Photo courtesy of Seabrook Station.

Hampton/Seabrook Harbor is the most popular, and most productive, area for recreational harvesting of soft shell clams in New Hampshire. Soft shell clams (*Mya arenaria*) are harvested from three large clam flats in the middle of Hampton/Seabrook Harbor as well as from other smaller flats in the harbor. The resource fluctuates over time. The most recent information from clam surveys indicates a standing crop of nearly 9,000 bushels of clams (NHEP, 2002a).

Figure 3: Clam standing stock in Hampton/Seabrook Harbor



Data courtesy of Seabrook Station

Despite being New Hampshire's primary clam resource, the clam flats in Hampton/Seabrook Harbor are often closed due to bacteria pollution. The DES Shellfish Program is responsible for classifying shellfish growing areas in New Hampshire. DES uses a set of guidelines and standards known as the National Shellfish Sanitation Program (NSSP) for classifying shellfish growing areas. The latest classifications for the waters in Hampton/Seabrook Harbor are shown in the following table.

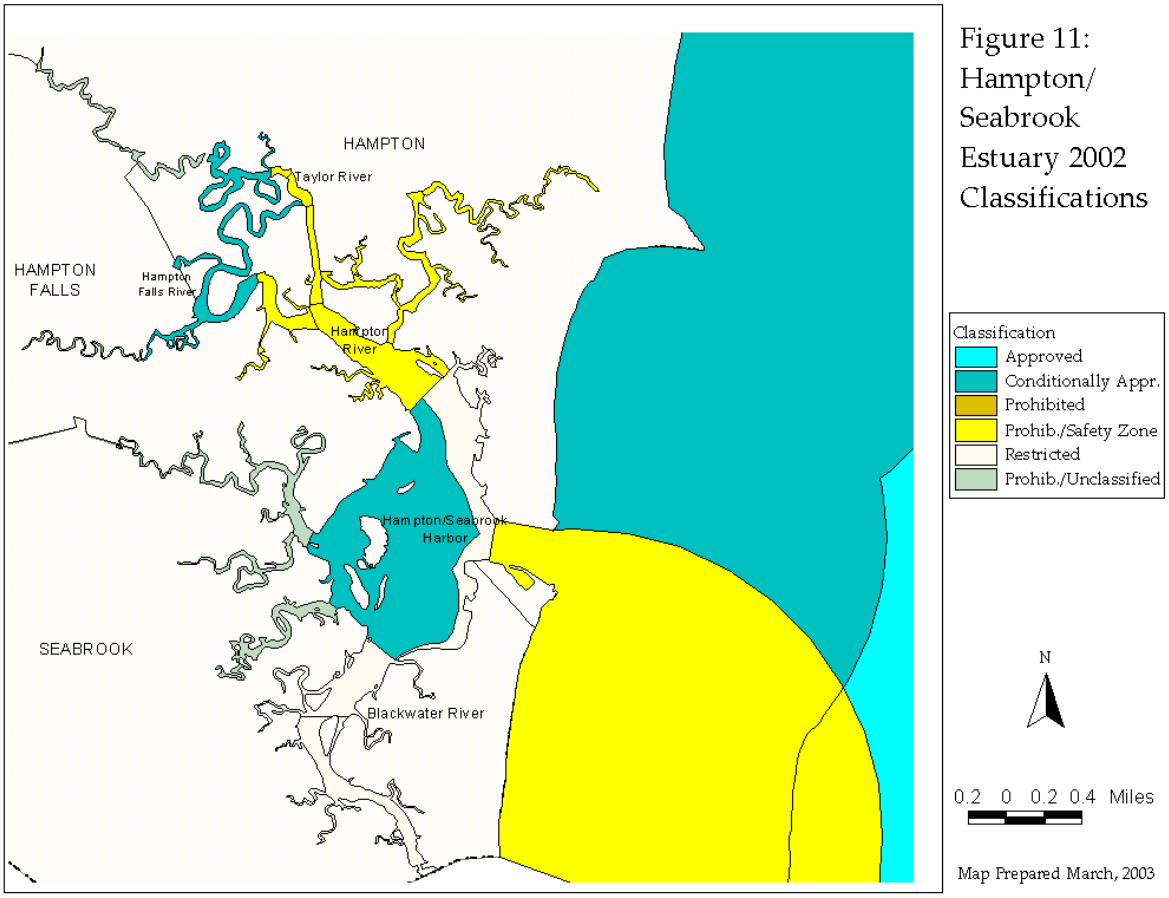
Table 4: Classification of growing areas in Hampton/Seabrook Harbor in 2002

Classification	Area	Location
Conditionally Approved	474 acres	Central harbor around Middle Ground, Common Island, and Confluence flats; portions of Hampton Falls River and Taylor River.
Prohibited/Safety Zone	208 acres	Hampton River and tributaries; portions of Hampton Falls River and Taylor River; Tide Mill Creek
Prohibited/Unclassified	101 acres	Browns River, Hampton Falls River, Hunts Island Creek, Mill Creek
Restricted	264 acres	Blackwater River, buffer between Harbor and Hampton Beach development.
Total	1,047 acres	

Source: DES Shellfish Program
Note: Table does not contain the tidal portion of the Taylor River upstream of the railroad bridge.

The following map illustrates which portions of Hampton/Seabrook Harbor are classified in the different categories.

Figure 4: Shellfishing Classifications for Hampton/Seabrook Harbor in 2002



Source: DES Shellfish Program

The “conditionally approved” classification for the central harbor area and the upper reaches of the Hampton Falls and Taylor rivers means that these areas are open during dry weather but closed after a rainfall of a specified magnitude for the period of November through May. The current rainfall closure threshold is 0.25 inches. Depending on the weather in a given year, the clam flats are closed due to rainfall for 40-70 percent of the weekends available for harvest.

The “prohibited/safety zone” area covering Hampton River and a portion of its tributaries is closed to shellfishing because this area could be affected by a failure of the Hampton WWTF before managers have time to close the area to harvesting. Designation of such areas is a standard requirement of the NSSP.

The areas classified as “restricted” constitute a buffer between the clam flats and the Hampton Beach development. The Blackwater River to the south is also considered restricted. In restricted areas, shellfish may be harvested only if permitted and subjected to a suitable and effective purification process (typically implemented by commercial operations). But because the area is harvested only by recreational diggers, the "restricted" designation effectively closes the area to all harvesting.

The remaining sections of the harbor are closed to shellfishing because they have not yet been classified.

The flats are closed by the N.H. Fish & Game Department in June, July, and August for resource conservation reasons. DES keeps the flats closed in September and October because the bacteria concentrations are typically elevated even though there tends to be little rainfall during this period. Additionally, a closure of this area during the months of September and October would also be appropriate because of the unacceptably large risk of boat sewage contamination present during this time.

Therefore, although Hampton/Seabrook Harbor is New Hampshire's major clam resource, the use of this resource is significantly restricted due to bacterial pollution. The central portion of the harbor with the greatest clam resource is closed to shellfishing after nearly every rainfall between November to May, and is closed in September and October due to dry weather impacts. Other areas of the harbor are currently closed throughout the year.

b. Applicable Water Quality Standards and Water Quality Numeric Targets

i. Overview

Water Quality Standards determine the baseline water quality that all surface waters of the State must meet in order to protect their intended uses. They are the "yardstick" for identifying where water quality violations exist and for determining the effectiveness of regulatory pollution control and prevention programs. The standards are composed of three parts: classification, criteria, and antidegradation regulations.

Classification of surface waters is accomplished by state legislation under the authority of RSA 485-A:9 and RSA 485-A:10. By definition, (RSA 485-A:2, XIV), "surface waters of the state means streams, lakes, ponds, and tidal waters within the jurisdiction of the state, including all streams, lakes, or ponds, bordering on the state, marshes, water courses and other bodies of water, natural or artificial."

All State surface waters are either classified as Class A or Class B, with the majority of waters being Class B. DES maintains a list which includes a narrative description of all the legislative classified waters. Designated uses for each classification may be found in State statute RSA 485-A:8 and are summarized below.

Classification	Designated Uses
Class A -	These are generally of the highest quality and are considered potentially usable for water supply after adequate treatment.

Discharge of sewage or wastes is prohibited to waters of this classification.

Class B - Of the second highest quality, these waters are considered acceptable for fishing, swimming and other recreational purposes, and, after adequate treatment, for use as water supplies.

Tidal waters, such as in Hampton/Seabrook Harbor, are Class B waters.

DES has developed a Comprehensive Assessment and Listing Methodology (DES, 2002c) in which the specific designated uses for New Hampshire waters have been defined as shown in the following table.

Table 5: Designated uses for New Hampshire waters

Designated Use	DES Definition	Applicability
Aquatic Life	Waters that provide suitable chemical and physical conditions for supporting a balanced, integrated and adaptive community of aquatic organisms.	All surface waters
Fish Consumption	Waters that support fish free from contamination at levels that pose a human health risk to consumers.	All surface waters
Shellfish Consumption	Waters that support a population of shellfish free from toxicants and pathogens that could pose a human health risk to consumers	All tidal surface waters
Drinking Water Supply	Waters that with conventional treatment will be suitable for human intake and meet state/federal drinking water regulations.	All fresh surface waters
Primary Contact Recreation (i.e. swimming)	Waters suitable for recreational uses that require or are likely to result in full body contact and/or incidental ingestion of water	All surface waters
Secondary Contact Recreation	Waters that support recreational uses that involve minor contact with the water.	All surface waters
Wildlife	Waters that provide suitable physical and chemical conditions in the water and the riparian corridor to support wildlife as well as aquatic life.	All surface waters

The second major component of the water quality standards is the "criteria." These are numerical or narrative criteria which define the water quality requirements for Class A or Class B waters. Criteria assigned to each classification are designed to protect the legislative designated uses for each classification. A waterbody that meets the criteria for its assigned classification is considered to meet its intended use. Water quality criteria for each classification may be found in RSA 485-A:8, I-V and in the State of New Hampshire Surface Water Quality Regulations (Env-Ws 1700).

The third component of water quality standards are antidegradation provisions which are designed to preserve and protect the existing beneficial uses of the State's surface waters and to limit the degradation allowed in receiving waters. Antidegradation regulations are included in Part Env-Ws 1708 of the New Hampshire Surface Water Quality Regulations. According to Env-Ws 1708.02, antidegradation applies to the following:

- All new or increased activity, including point and nonpoint source discharges of pollutants that would lower water quality or affect the existing or designated uses.
- A proposed increase in loadings to a waterbody when the proposal is associated with existing activities.
- An increase in flow alteration over an existing alteration.
- All hydrologic modifications, such as dam construction and water withdrawals.

ii. Water Quality Standards Most Applicable to Pollutant of Concern

There are three designated uses for tidal waters that are relevant to bacteria pollution: shellfishing, primary contact recreation, and secondary contact recreation (e.g., boating). The water quality standards applicable to these three designated uses are provided below.

The water quality standards for shellfishing waters are the NSSP standards for "approved" shellfish harvesting areas: a geometric mean for fecal coliforms of less than 14 MPN/100ml and a 90th percentile of less than 43 MPN/100ml as determined using NSSP protocols (RSA 485-A:8, V; ISSC, 1999). The NSSP guidelines include other factors besides attainment of these standards for growing area classifications (e.g., completion of sanitary surveys).

The water quality standards for primary contact recreation are: tidal waters used for swimming purposes shall contain not more than either the geometric mean based on at least three samples obtained over a 60 day period of 35 enterococci per 100 mL, or greater than 104 enterococci per 100 mL in any one sample, unless naturally occurring (RSA 485-A:8, V).

There are no water quality standards for secondary contact recreation. However, for the purposes of determining impaired waters for the 305b/303d lists, DES uses enterococci concentrations greater than five times the primary contact recreation standards to determine secondary contact recreation use support (DES, 2002c).

iii. Targeted Water Quality Goals

The goal for this TMDL is for the bacteria concentrations throughout Hampton/Seabrook Harbor to meet all the water quality standards for all the designated uses affected by bacteria pollution: shellfishing, primary contact recreation, and secondary contact recreation. Of these three designated uses, the water quality standards for shellfishing are the most stringent. Therefore, the targeted goal for this TMDL is for the water quality in Hampton/Seabrook Harbor to meet both aspects of the NSSP shellfishing standard (geomean and 90th percentile concentrations) as measured in accordance with NSSP protocols. It is expected that bacteria loading reductions needed to meet the NSSP standards will also cause primary and secondary contact recreation standards to be met. Follow-up monitoring, discussed in Section 6(b)(ii), will include measurements of both fecal coliforms and enterococci so that the water quality standards for all the designated uses can be assessed.

3. Hampton/Seabrook Harbor Receiving Water Quality Characterization

Data from the DES Shellfish Program monitoring program from 1993-2002 were used to characterize the baseline concentrations of fecal coliforms (FC) in Hampton/Seabrook Harbor. Fecal coliform measurements were compiled from the ten stations that surround and overlay the major clam flats in the harbor (see Figure 5 from the QAPP in Appendix A). Data from June, July, and August were excluded because the clam flats are closed by NHF&G during this period for resource conservation reasons. Only low tide samples (from three hours before low tide to 0.5 hours after low tide) were used because most of the samples collected during this period were from this tide stage. The FC results from the DES Shellfish Program are expressed as "most probable number per 100ml (MPN/100ml)." The precipitation value for each sample is the precipitation recorded at Seabrook Station on the day of sample collection (if the storm occurred before the sample was collected) plus the total precipitation recorded during the preceding three days. All data used for these calculations have passed the QA protocols of the DES Shellfish Program.

In addition to the fecal coliform data from the DES Shellfish Program, information on the results of two microbial source tracking studies and measurements of enterococci concentrations at the harbor stations are also presented in Sections 3(e) and 3(f), respectively.

a. Representativeness of Water Quality Stations

The Hampton/Seabrook Harbor study area consists of three different environments: the central harbor area where the main clam flats are located, the tidal tributaries flowing into the central harbor area, and the shoreline area between the developed portions of Hampton and Seabrook and the central harbor area. The NSSP stations are representative of the central harbor area where most people harvest shellfish because the stations are located around the perimeter of this area and are between any sources and this area. NSSP stations are also located at the points where tidal tributaries merge with the central harbor. For tidal river systems, the instream sampling locations are considered representative of river water quality because mixing carries bacteria past the sampling point with little time for die off. (In fact, the central harbor area also resembles a tidal river at low tide because it becomes a series of channels with the stations located in the middle of them.) Therefore, the only portion of the study area where the representativeness of the NSSP stations may be in question is the shoreline area between the developed portions of Hampton and Seabrook and the central harbor area. Most of the discrete stormwater pipes and all the marinas are located in this area so there is the potential for higher bacteria concentrations near the shore than out in the harbor. However, in accordance with NSSP guidance, this area is classified as "restricted" for shellfishing as a precaution against releases from the marinas. A restricted classification requires that any shellfish harvested in these areas be purified, which is typically only implemented by commercial operations. But because the area is harvested only by recreational diggers, the restricted designation effectively closes the area to all harvesting.

NSSP stations were established in certain locations to serve one of three purposes: (1) monitor the effect of known pollution source; (2) justify a boundary between two different classifications; or (3) monitor ambient water quality. The DES Shellfish Program monitors these stations using a "systematic random sampling design" in accordance with NSSP protocols. Specifically, approximately eight to ten sampling dates during the open season (September to May) are chosen in advance for each station. While these dates are not chosen at random, the weather patterns are random so the samples are effectively randomized across a range of possible weather conditions.

Therefore, the NSSP stations in Hampton/Seabrook Harbor should be considered representative of all areas except for near the shoreline of the developed areas of Hampton and Seabrook. However, in accordance with NSSP guidance, recreational shellfishing will always be prohibited in these near shore areas, regardless of water quality, because of the proximity of potential pollution sources. Consequently, exposure to bacteria via eating shellfish from this area should not occur. In certain areas where parking lots and other public places are near stormwater drains, there is the potential for public health risks from exposure to high bacteria concentrations in stormwater. DES does not have any measurements of enterococci concentrations in stormwater samples to evaluate the significance of this risk. The follow-up monitoring plan for this TMDL (Section 6(b)(ii)) includes some enterococci monitoring at easily accessible pipes to evaluate this exposure pathway. As discussed in Section 2(b)(iii), the goal for this TMDL is to meet bacteria water quality standards for shellfishing as well as primary and secondary contact recreation throughout Hampton/Seabrook Harbor. However, the targeted goal is attainment of shellfishing standards since these are the most stringent bacteria standards of the three designated uses.

b. Methods for Geometric Mean Fecal Coliform Calculations

For the NSSP, the geomean concentration is simply the geometric mean of the most recent 30 routine samples. Routine samples are collected using a systematic random sampling design so that these samples are representative of the conditions in the harbor. The DES Shellfish Program database contains 977 routine samples from the harbor stations over the past 10 years. In addition, the DES Shellfish Program has conducted many sampling runs targeted at specific conditions of interest, particularly wet weather events and autumn dry weather events. This work added an additional 694 samples to the database. More importantly, the sampling targeted at wet weather events has produced a sizeable collection of measurements during different size storms which is important for estimating the effect of different size storms on the harbor water quality. Therefore, rather than excluding the non-routine samples from the geomean calculation (as would be required under NSSP protocols), a weighted geometric mean (WGM) will be calculated using all the data in the DES Shellfish Program database with weighting factors to prevent bias due to the overabundance of wet weather samples.

For the WGM calculation, geometric mean concentrations were determined for each station for groups of samples collected after different size rainfalls. These geometric mean FC concentrations were combined through a weighted average based on the percentage of the year for which each size rainstorm typically occurs. The equation of the WGM calculation is:

$$WGM = \sum_i f_i \cdot GM_i$$

where:
WGM = Weighted Geometric Mean (MPN/100ml)

f_i = frequency of days per year between September and May of stormsize *i*.
GM_i = Geomean FC concentration for stormsize *i*.

A ten year record of rainfall for Portsmouth (1992-2001) was used determine the frequency of different storm sizes. Snowfall events were removed from this dataset so the frequencies only reflect liquid precipitation. After a rainstorm, elevated concentrations typically persist in the harbor for three days due to continued bacteria loading from the watershed (DPHS, 1994). Therefore, the frequency of days when the water quality in the harbor reflects wet weather conditions was calculated by multiplying the number of storm events per year by three. While three days was the typical amount of time that the poor water quality lasted, the duration of poor water quality was highly variable. Some large storms cause closures for four or more days, while the bacteria concentrations return to normal within one or two days for others. How long the high bacteria concentrations actually last depend on the amount of rainfall, the storm duration, the rate at which bacteria loads pass through the watershed, and the timing of the storm relative to the tidal cycle. For this TMDL report, three days was an approximation of the duration of water quality impairments for modeling purposes.

The number of rainfall events and their frequencies are summarized in the following table. The frequencies in the last column of this table were used for the f_i values in the WGM calculation.

Table 6: Frequency of rainstorms during September through May in Hampton/Seabrook Harbor

Storm Size Class	Average Number of Storms/Year	Average Number of Days Affected	Average Fraction of Year Affected
Dry	NA	152	0.553
0.01-0.10	9.5	28.5	0.104
0.11-0.25	5.1	15.3	0.056
0.26-0.50	7.5	22.5	0.082
0.51-0.75	5.7	17.1	0.062
0.76-1.00	4.3	12.9	0.047
1.01-2.00	6.5	19.5	0.071
>2.00	2.4	7.2	0.026

Data source: Daily precipitation records for Portsmouth, NH.

c. Methods for 90th Percentile Fecal Coliform Calculations

The second component of the NSSP standard is the 90th percentile fecal coliform concentration. NSSP protocols call for the 90th percentile concentration to be calculated by:

$$90th\%ile = 10^{(x+1.28 \cdot s_x)}$$

where
90th%ile = the 90th percentile FC concentration
x = the mean value of log transformed FC concentrations (base 10)
s_x = the standard deviation of the log transformed FC concentrations (base 10)

This equation was used to estimate the 90th percentile concentrations for the TMDL. However, implicit in this equation is the assumption that the FC data used to calculate x and s_x are a random sample of the water quality in the harbor. Therefore, only data collected during the routine (systematic random) sampling program can be used to estimate the 90th percentile concentrations. The samples were not split into different storm sizes because the 90th percentile concentration is based on the distribution of FC concentrations under all conditions.

d. Hampton/Seabrook Harbor Water Quality Statistics

The following table summarizes the WGM and 90th percentile FC concentrations for the ten harbor stations. These statistics were calculated using the methods described in the previous sections.

Table 7: Characterization of Fecal Coliform Concentrations in Hampton/Seabrook Harbor

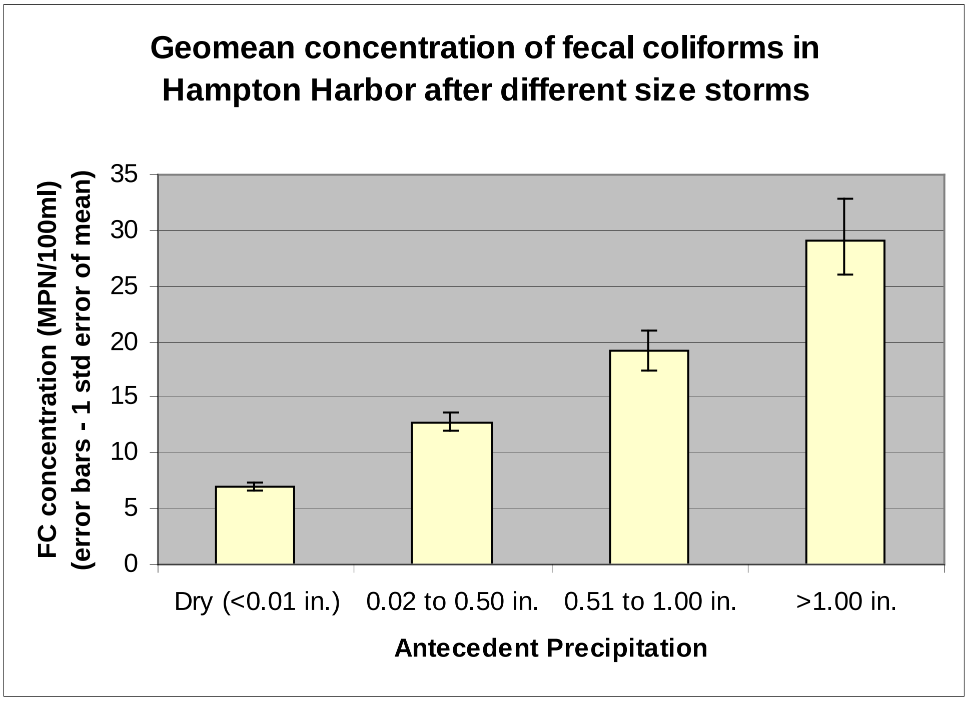
Station	Weighted Geomean (MPN/100ml)	90th %ile Concentration (MPN/100ml)
HH10	12	48
HH11	11	53
HH12	13	79
HH17	13	78
HH18	10	40
HH19	17	109
HH1A	14	75
HH2B	13	69
HH5B	13	58
HH5C	14	44
Average	**13**	**65**
NSSP Standard	**14**	**43**

Data Source: DES Shellfish Program, records from 1993-2002

These statistics illustrate that the weighted geomean concentrations are close to the water quality standard but that the 90th percentile concentrations are consistently higher than the standard. High 90th percentile concentrations indicate unacceptably high variability in FC due to periodic spikes, as opposed to chronically poor water quality. The most obvious source of periodic loading spikes is wet weather runoff. Another possible episodic source is boat discharge. The only portion of the estuary where the geomean standard is not met is the mouth of Mill Creek (HH19) which may indicate a chronic source of bacteria from this tributary.

The following figures illustrate the effect of wet weather runoff on FC concentrations in the harbor. In Figure 5, the geomean FC concentrations during different size storms are shown to increase steadily with increasing rainfall amount.

Figure 5: Geomean concentration of fecal coliforms in Hampton/Seabrook Harbor after different size storms



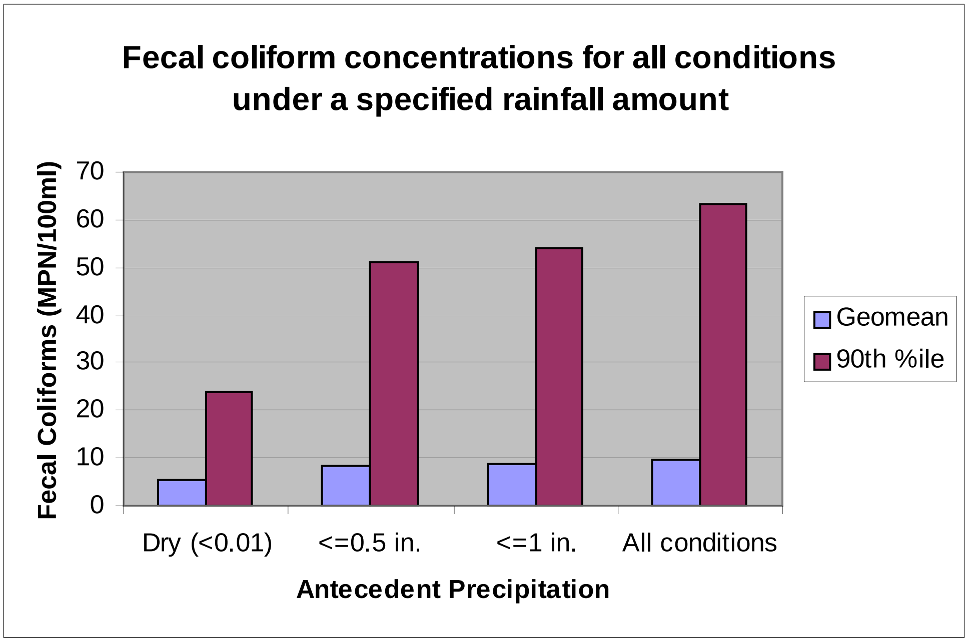
Data Source: DES Shellfish Program, 1993-2002, all low tide data, September to May

The elevated FC concentrations during wet weather events cause the geomean and 90th percentile concentration to increase as larger storms are included in the statistic calculation. To illustrate this, the geomean and 90th percentile FC concentrations were calculated for subsets of the routine samples:

- Only samples collected with antecedent precipitation <0.01 inches (n=437)
- Only samples collected with antecedent precipitation ≤0.50 inches (n=746)
- Only samples collected with antecedent precipitation ≤1 inches (n=873)
- All routine samples (n=977)

The following figure illustrates how the 90th percentile statistic increases more rapidly than the geomean statistic as more samples from larger rainfall events are added to the calculation.

Figure 6: Fecal coliform concentrations for all conditions under a specified rainfall amount



While wet weather loads are clearly important, a persistent trend of unacceptably high FC concentrations during dry weather in the autumn has also been noted by the DES Shellfish Program (DES, 2002a). The following table illustrates how geomean and 90th percentile FC concentrations during dry weather are much higher during the September-October period compared to the rest of the year.

Table 8: Yearly and autumn dry weather FC concentrations

Period	Sample Size	Geomean (MPN/100ml)	90th %ile (MPN/100ml)
September through May	437	5.56	24.05
September and October	97	16.87	80.77
November through May	340	4.05	12.80

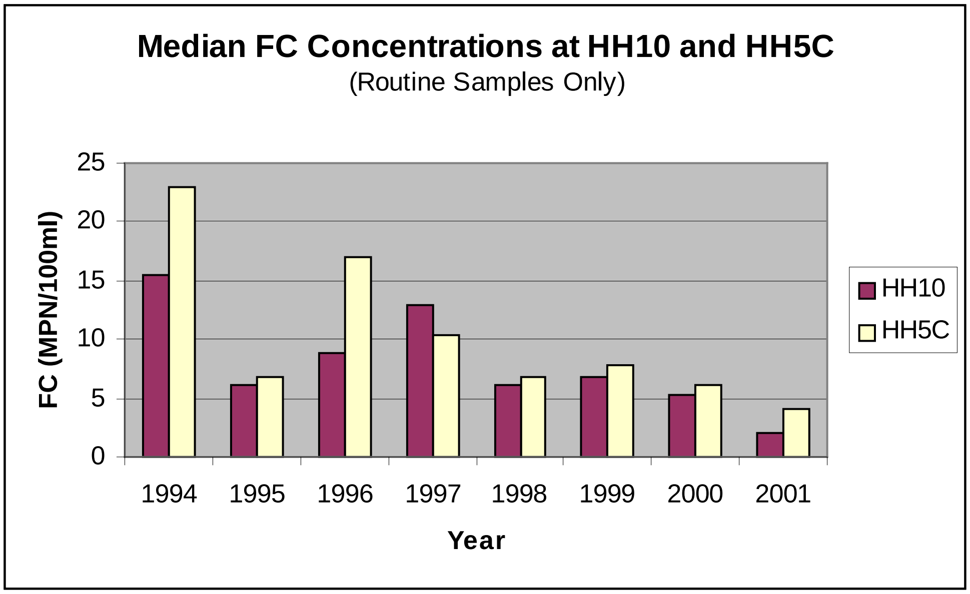
Data Source: DES Shellfish Program, 1993-2002, low tide, routine samples

The DES Shellfish Program keeps the clam flats closed in September and October due to these elevated FC concentrations and the unacceptably high risk of boat sewage contamination during this time.

e. Water Quality Trends

Trends in FC concentrations over time were assessed using the nonparametric Mann-Kendall Test on the yearly median FC concentrations. The yearly medians from 1994 through 2001 were used for this assessment because at least 5 routine samples were collected from each station during each of these years. Eight of the ten stations exhibited no significant trend. At HH10 and HH5C, downward trends were statistically significant at $p<0.1$ level. Figure 7 illustrates the trends in median FC concentrations at these two stations.

Figure 7: Median FC concentrations at HH10 and HH5C, 1994-2001



Based on this trend analysis, there do not appear to be any global trends in FC concentrations in Hampton/Seabrook Harbor over the past ten years. In the Hampton River (where HH10 and HH5C are located), there is evidence for a local trend of decreasing concentrations.

f. Microbial Source Tracking Results

Source species for *Escherichia coli* strains in Hampton/Seabrook Harbor were identified using a genetic fingerprinting technique called ribotyping. Ten sampling stations were monitored at least every two weeks from September 2000 through October 2001. Ribotyping analyses matched 60 percent of the ribotypes for *E. coli* isolates found in the water samples to the ribotypes for strains housed in the source species database at the University of New Hampshire. Sixty percent of the isolates were matched, with 15 percent identified as wildlife sources, 7 percent as avian sources, 26 percent as human sources, 4 percent as pets and the remaining 8 percent as livestock.

The ribotyping analyses showed that roughly one-quarter of the sources were wild animal sources (wildlife and avian) during both wet and dry weather conditions. These data show that the percentage of *E. coli* isolate types found in the harbor are relatively consistent with regard to weather conditions (Table 9). The combined wildlife and avian types were identified in 21 percent and 24 percent of the isolates during wet and dry weather, respectively.

Table 9: Relative percent of source species for E. coli strains in Hampton/Seabrook Harbor for various weather conditions: 2000-2001

Source Species	All weather	Wet weather	Dry weather	Autumn Dry weather
Wildlife	15%	14%	17%	14%
Avian	7%	7%	7%	8%
Human	26%	26%	26%	27%
Pets	4%	2%	5%	4%
Livestock	8%	7%	9%	8%
Unidentified	40%	43%	36%	39%

Data Source: UNH/DES Ribotyping Project (Jones and Landry, 2003)

As discussed above, 40 percent of the ribotypes for isolates were not matched to known source species strains. This deficiency makes it difficult to draw firm conclusions about the relative proportions of different bacteria sources to the harbor. The percent of strains from human-related sources (human, pets, livestock) could be between 38 percent (if none of the unmatched strains were from human related sources) and 78 percent (if all the unmatched strains were from human related sources). Likewise for wild animal sources, the relative percent of strains could range from 22 percent (if none of the unmatched strains were from wildlife or avian sources) to 62 percent (if all of the unmatched strains were from wildlife or avian sources). The ranges shown above represent extremes because it is unlikely that all of the unmatched strains would be just human-related or just wild animal related. In reality, the relative proportions of the human-related and wild animal sources will probably be toward the middle their possible ranges. Therefore, in the absence of more information, it will be assumed that the ratio of human-related sources to wild animal sources is approximately 60:40.

DES collected samples from two stormwater sources for ribotyping analysis during the TMDL study. One of the pipes chosen for this study was HHPS069 which is in Hampton, and drains multiple catch basins along Ashworth Avenue. The other source was HHPS182 which receives stormwater from the River Street pump station in Seabrook. Five samples from each source were collected at hourly intervals during a large rainstorm on October 16, 2002. The results from these samples are shown in the following table.

Table 10: Relative percent of source species for E. coli strains in stormwater from two stormwater pipes, 2002

Source Species	HHPS069	HHPS182	Both Pipes
Wildlife	13%	17%	15%
Avian	46%	29%	36%
Human	13%	26%	20%
Pets	4%	9%	7%
Livestock	0%	0%	0%
Unidentified	25%	20%	22%

Data Source: UNH/DES Ribotyping Project (Jones, 2003)

At both pipes, birds were the largest relative source of bacteria, followed by humans and wildlife. Human related sources (human, pets, livestock) accounted for 17 percent and 35 percent of the isolates in HHPS069 and HHPS182, respectively. These results differ from the relative source strengths determined from the samples collected in the harbor. However, the harbor results are based on sampling data collected throughout the year at ten stations. The data for the pipes is from two pipes sampled during one storm. The relative distribution of sources for the pipes may change during the year due to large changes in the population of the beach areas during the summer. Therefore, the data from the harbor study should be more representative of the cumulative bacteria pollution to the harbor. The data from the two pipes is still useful for designing remediation plans for these two sources and, importantly, for identifying the presence of human-sourced bacteria in stormwater.

g. Water Quality Relative to Swimming Standards

During 2001, four stations in central portion of Hampton/Seabrook Harbor were monitored for enterococci monthly between May and September. The data from these samples are shown in the following table.

Table 11: Enterococci data for Hampton/Seabrook Harbor, 2001

Station	Date	Enterococci (cts/100ml)	Geomean* (cts/100ml)	Comments
HH10	5/21/2001	4		
HH10	6/12/2001	30	6.2	
HH10	7/16/2001	2		
HH10	8/23/2001	50		
HH10	9/25/2001	10		Ave of dupes (10 and <10)
HH19	5/21/2001	1		
HH19	6/12/2001	240	9.0	
HH19	7/16/2001	3		
HH19	8/23/2001	60		
HH19	9/25/2001	10		
HH1A	5/21/2001	5		
HH1A	6/12/2001	20	4.6	
HH1A	7/16/2001	1		
HH1A	8/23/2001	40		
HH1A	9/25/2001	10		
HH2B	5/21/2001	10		
HH2B	6/12/2001	80	4.3	
HH2B	7/16/2001	0.1		Result was 0 but set to 0.1 to allow for geomean calc.
HH2B	8/23/2001	40		
HH2B	9/25/2001	10		

Shaded cells denote >104/100ml single sample standard or >35/100ml 60-day geomean standard.
* Geomean of the 3 samples collected within the 60 day period between 5/21/01 and 7/16/01at each station.

The results of this monitoring program show that the water quality in the harbor met the water quality standards for swimming (primary contact recreation) during this period. The sample collected from station HH19 on June 12, 2001 was higher than the single sample standard of 104 counts/100ml. However, following the procedure for determining impairments in New Hampshire's Consolidated Assessment and Listing Methodology (DES, 2002c), the frequency of exceedences was too low to consider the waterbody to be impaired for the designated use.

In Section 2(a), it was discussed that two of the 14 assessment units that constitute the harbor are listed as impaired for primary contact recreation (e.g., swimming) on New Hampshire's 2002 303(d) list. However, the primary contact recreation impairments are based on reports of discharges of untreated sewage (e.g., sanitary sewer overflows, wastewater treatment bypasses) in these assessment units. In contrast, as shown in this section, water quality measurements in the harbor indicate that State standards for swimming are being met.

4. Source Characterization

a. Existing Point Source Loads

Point source discharges include discernible, confined, and discrete conveyances such as the discharge from the effluent pipes of wastewater treatment plants. In addition, discrete stormwater discharges from municipal separate storm sewer systems (MS4) covered by the Phase II stormwater program regulations are considered point sources for this TMDL (EPA, 2002b). All point source discharges must have a State Surface Water Discharge permit and a federal National Pollutant Discharge Elimination System (NPDES) discharge permit.

i. Wastewater Discharges

The only significant bacteria point source discharging to Hampton/Seabrook Harbor is the Hampton municipal wastewater treatment facility (WWTF). There are two other permitted sources for bacteria discharges to the estuary, EnviroSystems, Inc. (NPDES # NH0022055) and Aquatic Research Organisms, Inc. (NPDES # NH0022985), but their discharges are negligible.

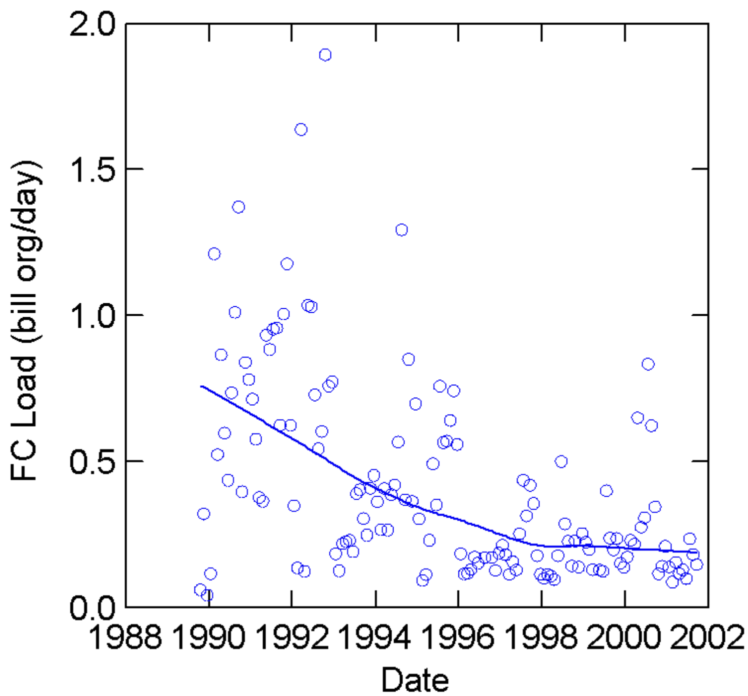
Bacteria loads from the Hampton WWTF were estimated using Discharge Monitoring Reports from 1989 to 2001 that reported total coliform concentration in the effluent and the average effluent discharge rate for each month. The geometric mean loading rate from the facility is 0.3 billion fecal coliform organisms per day (bill org/day). The fecal coliform loading rate was estimated from the total coliform data by assuming that 20 percent of total coliform bacteria are fecal coliforms. This assumption is based on the ratio between the fecal coliform and total coliform NSSP geomean standards (14 MPN/100ml for FC, 70 MPN/100ml for TC). Moreover, TC to FC ratios from effluent sampling at other WWTFs support this conversion factor. The Dover WWTF and Durham WWTF recently switched from measuring total coliforms in effluent samples to fecal coliforms. The ratio of the median TC concentration before the switch to the median FC concentration after the switch ranged from 16-26 percent for these two plants.

The following figure illustrates the trend in bacteria loading from the Hampton WWTF. Over the period of 1989-2001, the loading has decreased by 91 percent. Most of the decrease was due to decreasing bacteria concentrations in the effluent, not decreasing flows (NHEP, 2002b).

According to its permit for 2002-2006, the Hampton WWTF is permitted to discharge effluent with a monthly average FC concentration of 14 MPN/100ml and a daily maximum FC concentration of 43 MPN/100ml (EPA, 2002). The design flow for the facility is 4.7 million gallons per day (EPA/DES, 2002), although the largest possible flow through the plant is actually less than this amount due to the nitrification process (Stephanie Larson, DES, *pers. com.*). Therefore, under the existing permit, the WWTF can discharge a maximum of 7.7 billion organisms per day.

Estimates of bacteria loads from the Hampton WWTF are based on measurements of bacteria in treated effluent from discharge monitoring reports. The loading estimate does not take into account loadings from the plant due to emergency bypasses of untreated or partially treated wastewater during storm events or other temporary system failures.

Figure 8: Fecal coliform load from the Hampton WWTF, 1990-2002



ii. Stormwater Discharges from Phase II MS4 Systems

The towns of Hampton and Seabrook are covered by the EPA Phase II stormwater program regulations. Therefore, stormwater discharges from discrete pipes and conveyances in these towns are considered point sources for this TMDL. Over 100 pipes, streams, creeks, and conveyances of stormwater have been identified around Hampton/Seabrook Harbor by the DES Shellfish Program and the DES Watershed Assistance Section. During 2002, DES selected the 16 stormwater sources most likely to be large contributors of bacteria to the harbor and monitored them for bacteria loads during two storms. The locations of the monitored stormdrains are shown in Appendix A.

Bacteria loads from the 16 sources were monitored during two storms. The first storm on July 23, 2002 was a short, but intense rainstorm that dropped 0.33 inches of precipitation over four hours. The second storm on October 16, 2002 was a classic Nor'easter with soaking rain and high winds lasting over 12 hours. A total of 1.39 inches of rain fell during the second storm. Total precipitation during the two storms was taken from Seabrook Station precipitation records. Since these two storms were so different, the monitoring results from each day are assumed to bracket the range of possible loadings.

The results of the study are shown below in Table 12 containing the average fecal coliform concentration in stormwater and Table 13 containing the loading values for each source during the two storms. For more information on the individual stormdrains and the methods used to collect the stormwater samples and calculate the loads, refer to the QA Project Plan for the study (DES, 2002b). Summary tables of the FC concentrations, flow data, and any additional methods not covered by the QA Project Plan are included in Appendix B (DES, 2003a). Appendix C contains an audit of the sampling and data handling procedures by the Project Manager. The Project QA Officer's concurrence report in attached as Appendix D.

Table 12: Average concentrations of fecal coliforms in stormwater samples from MS4 stormdrains on July 23, 2002, October 16, 2002, and October 17, 2002

Date	7/23/2002		10/16/2002		10/17/2002	
Precip	0.33 in		1.39 in		NA	
Units	(cfu/100ml)	(#)	(cfu/100ml)	(#)	(cfu/100ml)	(#)
HHPS015	1,500	n=4	2,820	n=5	700	n=1
HHPS016	1,675	n=4	4,000	n=5	2,000	n=1
HHPS055	100	n=4	2,920	n=5	No Data	NA
HHPS056	600	n=4	2,120	n=5	No Data	NA
HHPS057	No Data	NA	50	n=1	No Data	NA
HHPS061	No Data	NA	13,560	n=5	No Data	NA
HHPS062	No Data	NA	6,020	n=5	No Data	NA
HHPS063	150	n=2	4,540	n=5	No Data	NA
HHPS066	7,062	n=6	11,600	n=8	No Data	NA
HHPS067	9,450	n=4	14,150	n=6	No Data	NA
HHPS068	4,900	n=6	2,900	n=8	No Data	NA
HHPS069	4,500	n=6	8,763	n=8	No Data	NA
HHPS070	725	n=4	7,180	n=5	No Data	NA
HHPS071	1,267	n=3	1,968	n=5	No Data	NA
HHPS072	5,933	n=3	2,950	n=4	No Data	NA
HHPS182	5,375	n=4	8,600	n=5	No Data	NA
Average for Hampton Beach stormdrains (2)	3,469		6,055			

(1) Results reported as "below detection limit" were assigned a value of the detection limit to calculate the average.
(2) Hampton Beach stormdrains are all the sources on this table except HHPS015, HHPS016, and HHPS182.

Table 13: Summary of bacteria loads from stormdrain sources monitored in 2002

Source	Pipe Diameter	Bacteria Load (7/23/02) 0.33 inch rain	Bacteria Load (10/16/02) 1.39 inch rain	Percent of Total Load (7/23/02)	Percent of Total Load (10/16/02)	Comments
	(in)	(bill org)	(bill org)	(%)	(%)	
HHPS061	20	no info	0.0		0%	No Flow
HHPS062	10	no info	4.1		1%	
HHPS073	12	no info	0.0		0%	No Flow
HHPS072	18	5.2	7.7	4%	1%	
HHPS071	28	0.6	4.7	0%	1%	
HHPS070	28	0.2	14.7	0%	2%	
HHPS054	12	0.0	0.0	0%	0%	No Flow
HHPS055/056	18/36	0.0	5.0	0%	1%	No flow 7/23
HHPS057	18	0.0	0.0	0%	0%	No Flow
HHPS015	42	1.7	10.8	1%	2%	
HHPS016	60	11.1	138.4	9%	22%	
HHPS066	36	13.9	67.0	12%	11%	
HHPS067	12	1.1	10.0	1%	2%	
HHPS068	36	0.1	24.0	0%	4%	
HHPS069	36	14.2	98.2	12%	16%	
HHPS182	30	71.8	245.7	60%	39%	
Subtotal		**119.8**	**630.3**	**100%**	**100%**	

The results of the DES stormwater sampling show that the loading from monitored stormdrain sources was approximately 120 billion organisms during the storm on July 23, 2002 and 630 billion organisms on October 16, 2002. As a point of reference, the average loading from the Hampton WWTF is 0.3 billion organisms per day and its maximum permitted daily load is 7.7 billion organisms per day. Therefore, during storm events, there can be significant bacteria loads to the harbor from MS4 stormdrains.

b. Existing Non-Point Source Loads

In general, non-point sources (NPS) of pollutants include all pollutant sources other than point sources. Compared to point sources, NPSs of pollution are diffuse and more difficult to quantify. Examples of NPSs include stormwater runoff not conveyed through MS4 systems and diffuse sources such as failed septic systems. In Hampton/Seabrook Harbor, the three major non-point sources are (1) discharges from boats in mooring fields or marinas, (2) dry weather human and wildlife non-point sources, and (3) stormwater runoff (via tributaries or other non-MS4 sources).

i. Marinas/Boats

Many large boats are moored or docked in Hampton/Seabrook Harbor. Releases of untreated sewage from these boats could contribute to the FC concentrations in the harbor. On October 17, 2002, the DES Shellfish Program observed that 52 of the 143 slips at the Hampton River Marina were filled and that 15 boats were present in each of the two mooring fields (Hampton River and Seabrook Harbor). During the summer, the DES Shellfish Program observed that all the slips at the marina were filled on August 14, 2002. The number of boats in the mooring fields in August was not recorded but it will be assumed to be at least twice as many as were present in October (assume 30 boats in each field).

For a programmatic review of the DES Shellfish Program, the US Food and Drug Administration evaluated the Hampton River Marina and estimated that 50 percent of the boats in the slips discharge untreated sewage (USFDA, 2002). In the mooring fields, information from the DES Shellfish Program (Chris Nash, *pers. com.*) indicates that moored boats are mainly commercial vessels and often operate out at sea. Following DES Shellfish Program Classification Policies and Procedures (DES, 2003b), it can be conservatively assumed that only half of these moored boats have marine sanitation devices and only half of these boats would discharge in the harbor. Using these assumptions, the number of discharging boats ranged from 86 in August 2002 to 33 in October 2002 (see Table 14).

Table 14: Boats counts in Hampton/Seabrook Harbor from DES Shellfish Program

Date	Location	Number of Boats	Percent with heads	Percent discharging	Number of boats discharging
8/14/02	H.R. Marina	143	100%	50%	71
	Mooring Fields	60	50%	50%	15
10/17/92	H.R. Marina	52	100%	50%	26
	Mooring Fields	30	50%	50%	7

Following DES Shellfish Program Classification Policies and Procedures (DES, 2003b), the bacteria load from these boats can be estimated by the following equation:

$$\textit{FC Load} = (\textit{2 billion organisms/person}) \times (\textit{2 persons/boat}) \times (\textit{Number of boats discharging})$$

Using this equation, an estimate of the bacteria loads from boat discharges would be 132-344 billion organisms per day. The average value (238 billion FC organisms per day) will be used in subsequent calculations as a central tendency estimate.

The assumptions used to arrive at this value are conservative and likely overestimate the load from boat discharges for much of the year, except possibly the fall. During the fall, it is possible that there are more discharges from marine sanitation devices as boats are hauled from the water for winter storage.

ii. Modeled Dry-Weather Non-Point Source Loads

Sources of bacteria to the harbor during dry weather are a combination of human and wildlife/natural processes. Examples of possible dry weather human sources are failing septic systems and illicit discharges of wastewater to the stormwater system. Bird and wild animal waste is an example of a non-human source of bacteria to the harbor during dry weather.

A mass balance model was used to estimate the baseline loading of bacteria to the harbor during dry weather. There are four basic premises of the model:

- During dry weather conditions, the only sources of bacteria to the harbor should be the WWTF, boat discharges, and dry-weather non-point sources (both natural/wildlife and human).
- The largest mechanism to remove bacteria from the harbor is tidal flushing. Eighty-eight percent of the water in the estuary (4.2 billion gallons) is exchanged on each tide and very little of the exported water is drawn back into the estuary on the return tide (NAI, 1977). Therefore, the export of bacteria from the harbor over one tidal cycle will be approximately equal to the tidal prism volume (3.7 billion gallons) multiplied by the average FC concentration.
- The FC concentrations in the harbor are relatively constant during dry weather periods. The majority of the dry weather observations are within one order of magnitude (i.e., 67 percent of the observations are between 2 and 25 MPN/100ml). The DES Shellfish Program has found no significant differences between FC concentrations at high tide and low tide. Therefore, it is possible to assume steady state conditions.
- Since FC concentrations remain constant in the harbor, FC bacteria must be added to the harbor at a rate equal to the removal rate from tidal flushing.

The model predicts the total FC loading that is needed to maintain the constant dry weather FC concentrations in the harbor given the rate of bacteria removal due to tidal flushing. The baseline dry weather loading is the difference between the estimated total load from the model and the estimated loadings from WWTF and boat discharges from the previous sections. The equation for the model is:

Change in Number of Bacteria in Harbor = Sources - Sinks

$$\frac{\Delta(C \cdot V)}{\Delta t} = k_b + k_w + k_d - C \cdot \frac{V_{TP}}{\Delta t} \cdot CF$$

Variable Definitions:
C = concentration of fecal coliform bacteria in the waterbody (MPN/100ml)
V = Estuary volume (gallons)
Δt = time step in increments of whole tidal cycles = 0.52 days
k_b = baseline load of NPS bacteria during dry weather conditions (billion organisms per day)
k_w = WWTF load = 0.3 billion organisms per day
k_d = Load from boat discharges = 238 billion organisms per day
V_{TP} = Tidal exchange volume, equal to the difference between high tide and low tide volumes = 3.7 billion gallons (NAI, 1977)
CF = Conversion factor = 3.785E-08 (100ml*bill org)/(gallon*MPN)

Assuming steady-state conditions ($\Delta CV/\Delta t=0$), this equation reduces to a balance of sources and sinks:

$$Total\_Sources = k_b + k_w + k_d = C \cdot \frac{V_{TP}}{\Delta t} \cdot CF = Total\_Sinks$$

which can be solved for k_b:

$$k_b = -k_w - k_d + C \cdot \frac{V_{TP}}{\Delta t} \cdot CF$$

The geomean concentration of FC in the harbor during dry weather is 7 MPN/100ml based on the 662 available dry weather records in the DES Shellfish Program database. Therefore, the total tidal flushing export of bacteria from the harbor during dry weather must be equal to 1,891 billion organisms per day (k_b= -0.3–238+7*[3.7E+09/0.52]*3.785E-08 = 1891 bill org/day). For steady state to be maintained, the sum of the sources (k_b + k_w + k_d) must equal this amount also. Subtracting the estimated loadings for WWTF and boat discharges (0.3 billion org/day and 238 billion org/day), the baseline dry weather NPS loads (k_b) must amount to 1,653 billion org/day.

The baseline dry weather non-point source loads have a combination of human and non-human bacteria sources. The microbial source tracking data presented in Section 3(e) show that the ratio of human-related sources to wild animal sources (wildlife and avian) during dry weather is approximately 60:40. Therefore, the baseline dry weather NPS load can be split into a dry weather human-related source load of 992 billion organisms per day and a dry weather wild animal source load of 661 billion organisms per day.

iii. Stormwater Loads from Tributaries

There are seven major tributaries that drain the watershed around Hampton/Seabrook Harbor (Figure 2). During storms, the flow in these rivers increases as stormwater throughout the watershed is funneled into the harbor. Therefore, the tributaries could be considerable sources of bacteria to the harbor.

To understand the significance of the tributaries as bacteria sources, DES monitored the seven major tributaries to the harbor during two storms in 2002 (DES, 2003a). FC concentrations in each of the tributaries was monitored approximately hourly during two storms. Using a stage discharge relationship, it was possible to estimate flow (and, therefore, load) from one of the tributaries, Mill Creek. This tributary consistently had the highest concentrations of FC. The results of the monitoring are shown in Table 15.

Table 15: Summary of fecal coliform concentrations in wet weather tributary samples (2002)

Tributary	Station	N (7/23/02)	Mean FC Conc. (7/23/02)	FC Load (7/23/02)	N (10/16/02)	Mean FC Conc. (10/16/02)	Conc. (10/17/02) (n=1)	FC Load (10/16/02)
		(#)	(cfu/100ml)	(bill org)	(#)	(cfu/100ml)	(cfu/100ml)	(bill org)
Blackwater River	HHT1	4	50	NA	5	41	40	NA
Mill Creek	HHT2	4	500	9.75	5	412	1960	25.60
Hampton Falls River	HHT4	4	88	NA	5	107	30	NA
Taylor River	HHT5	4	125	NA	5	22	980	NA
Browns River	HH35	3	22	NA	1	10	20	NA
Hampton River	HH15	3	10	NA	1	<10	40	NA
Tide Mill Creek	HHT8	3	67	NA	5	82	30	NA

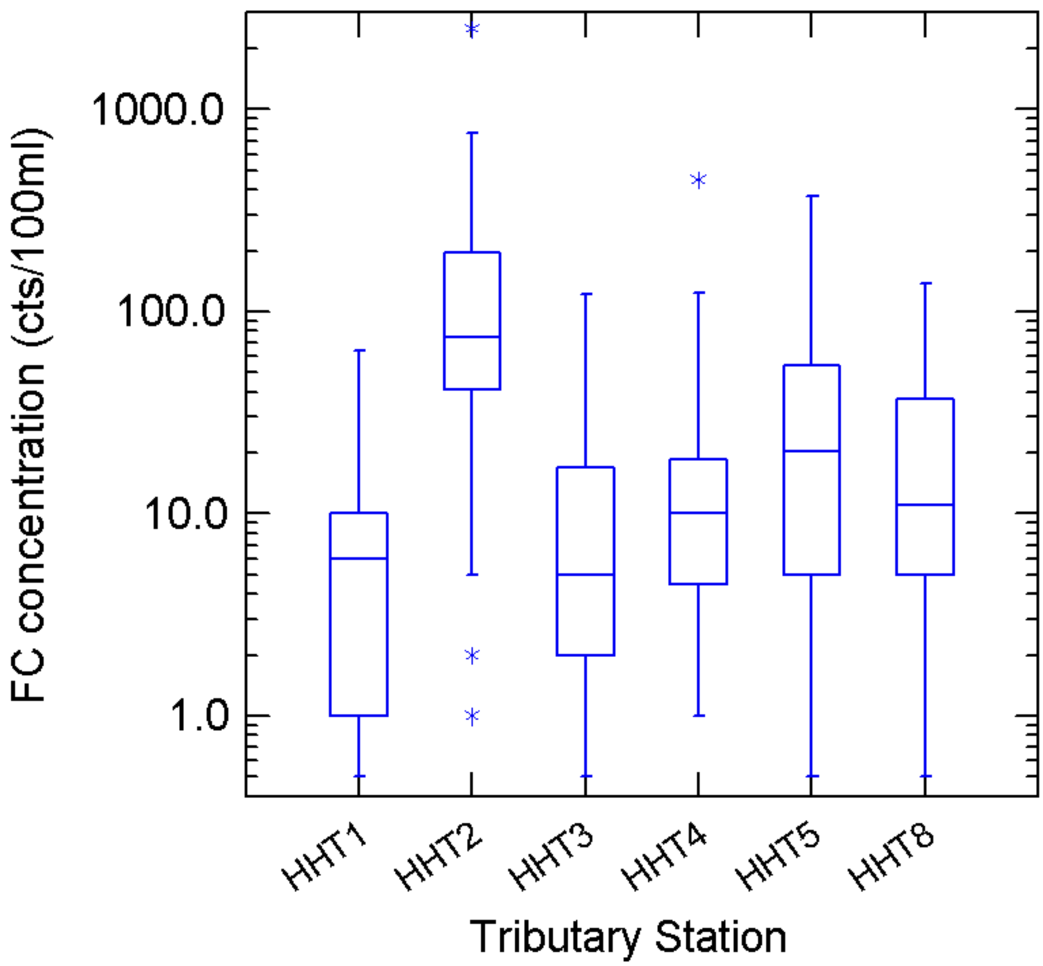
Mean values calculated using 1/2 the method detection limit (MDL) for samples reported as “<MDL” and the value for samples reported as “>value.”

The tributary sampling showed that the highest concentrations were in Mill Creek (HHT2). This pattern matches the observation that the highest weighted geomean FC concentration among the harbor stations is at HH19 at the mouth of Mill Creek.

The loading during the two storms from Mill Creek ranged from 10 to 26 billion organisms per day. These loading estimates are probably lower than the actual load from this tributary because the station was only monitored during the storm and runoff from the watershed would have continued for hours or days after the storm. For example, the concentration at HHT2 on the day after the second storm (October 17, 2002) was nearly five times higher than the average concentration measured during the storm on October 16, 2002.

In 2000, the DES Shellfish Program and the U.S. Geological Survey collected 35 samples from five of the stations monitored during the TMDL study (USGS/DES, 2002). The three-day antecedent rainfall for these samples ranged from 0 to 1.26 inches. Figure 9 shows box plots of FC concentration distribution from each station.

Figure 9: Box plots of FC concentrations at tributary stations, 2000

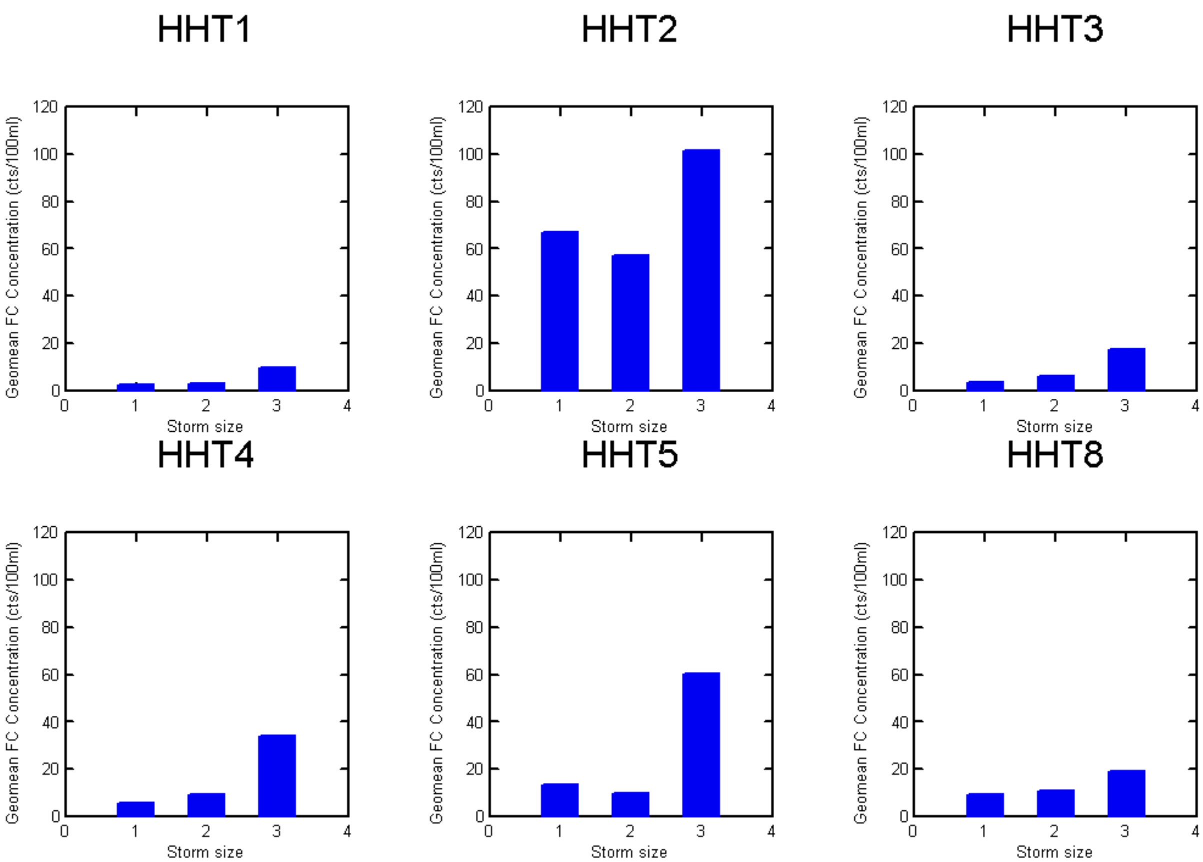


The FC concentrations at each station after different size rainfall events are summarized in the table and figure on the next page.

Table 16: Geomean FC concentration at tributary stations for different size storms, 2000

Station	Dry (<=0.01 in)		0.02 to 0.50 in		>0.50 in		All Conditions	
	N	Geomean (cfu/100ml)	N	Geomean (cfu/100ml)	N	Geomean (cfu/100ml)	N	Geomean (cfu/100ml)
HHT1	14	3	13	3	8	10	35	4
HHT2	14	67	13	57	8	101	35	69
HHT3	14	3	13	6	8	17	34	6
HHT4	14	6	13	9	8	34	35	10
HHT5	14	13	13	10	8	60	35	17
HHT8	14	9	13	11	8	19	35	12

Figure 10: Geomean FC concentrations at tributary station during different size storms, 2000



Note: Stormsize "1" is dry weather (<=0.01 inches precip)
Stormsize "2" is mild wet weather (0.02 to 0.50 inches precip)
Stormsize "3" is wet weather (>0.50 inches precip)

Note: Station HH3, located on the grounds of the Seabrook Station nuclear power plant, was not monitored during the TMDL study due to post-9/11 heightened security measures. The DES Shellfish Program data from 2000 illustrate that the FC concentrations in this tributary are similar to the other tributaries except for HHT2.

The DES Shellfish Program data confirm the observations from the TMDL tributary sampling, primarily that the concentrations at HHT2 are an order of magnitude higher than the other tributaries. As with the TMDL sampling, the tributary with the second highest concentration was the Taylor River (HHT5). Finally, the FC concentrations in the tributaries appear to respond slowly to precipitation.

Since only the flows at Mill Creek (HHT2) are known, it is only possible to estimate the load from this tributary, which ranged from 10 to 26 billion organisms per day during the two storms. In order to evaluate the significance of the loads from all tributaries relative to other sources, it would be helpful to know the total load from all the tributaries. The TMDL data and DES Shellfish Program data show that FC concentrations in the other tributaries are lower than those measured in Mill Creek. However, the other tributaries are larger than Mill Creek and have more flow and, therefore, could have sizeable loads. Therefore, as a rough, order-of-magnitude estimate, it will be assumed that the loading from each of the other tributaries is roughly equal to or less than the load from Mill Creek. Using this assumption, the total load from the seven tributaries together would be 68 to 179 billion organisms per day.

iv. Modeled Total Stormwater Load

Over 100 stormwater sources (pipes, creeks, conveyances) have been identified around Hampton/Seabrook Harbor. It was physically impossible to monitor all of these sources during the TMDL sampling rounds. Therefore, as previously mentioned, only 16 of the over 100 potential MS4 stormwater pipes, ditches, and conveyances, and only one of the seven tributaries to the harbor were monitored for bacteria loads during the DES sampling program (DES, 2003a). Overland stormwater flow directly to the harbor from developed areas and salt marshes will also contribute to NPS loading but is impossible to monitor. Therefore, two simple models were employed to provide estimates of the total stormwater load during the two storms. The modeled total loads can be compared to the monitored loads to determine what fraction of the total stormwater load was conveyed by the 16 MS4 stormdrains described in Section 4(a)(ii).

<u>Hampton Beach Runoff Model</u>

The first model is a simple infiltration-runoff model for the Hampton Beach area. The Hampton Beach area is a narrow spit of heavily developed land that runs north-south from the harbor mouth to the north end of Hampton Beach. A majority of the stormdrains monitored for the TMDL were located in this area because of its proximity to the shellfish growing areas and the large number of stormdrains. Stormwater infrastructure maps from the Hampton Department of Public Works show that the stormdrains monitored by DES should channel most of the stormwater discharged into the harbor from the area south of Ocean Boulevard. Hampton DPW staff estimated that 25-50 percent of the land surface is covered by impervious surfaces in the developed area.

The volume of stormwater runoff from the Hampton Beach area can be estimated from the following equation:

$$V_{storm} = C \cdot I \cdot A \cdot CF$$

Where
V_{storm} = volume of stormwater runoff (liters)
C = Runoff coefficient = 0.05 + 0.91× %impervious surface = 0.35 for an average %impervious surface value of 33% (equation from Schueler, 1987)
I = Rainfall intensity = 0.33 in for 7/23/02 storm and 1.39 for 10/16/02 storm
A = Area = 156 acres (estimated from digital orthophoto maps)
CF = Conversion factor = 102,802 (ft*l)/(in*acre-ft)

Multiplying the total stormwater volume by the average FC concentration monitored in the stormwater from stormdrains in this area (3,500 and 6,000 cts/100ml for July 23, 2002 and October 16, 2002, respectively, as shown on Table 12), the total load of bacteria from this area can be estimated to be 65 billion organisms on July 23, 2002 and 468 billion organisms on October 16, 2002. Table 17 shows this calculation.

Table 17: Modeled FC loads from Hampton Beach area

Parameter	Units	7/23/2002	10/16/2002
Monitored Load	billion org	35.5	235.4
Area	acres	156	156
Rainfall	in.	0.33	1.39
Rainfall	ft.	0.028	0.167
Runoff Coefficient	unitless	0.35	0.35
Stormwater Volume	acre-feet	1.50	6.32
Stormwater Volume	liters	1.85E+06	7.80E+06
Ave FC in stormwater	cts/100ml	3500	6000
Predicted Load	billion org	64.8	468.1
Ratio of Monitored Load to Predicted Load	Percent	55%	50%

The monitored loads from stormdrains in the Hampton Beach area were 36 and 235 billion organisms on July 23, 2002 and October 16, 2002, respectively. On July 23, 2002, the storm was short and intense and the stormdrains were monitored for the entire storm duration. Approximately 55 percent of the stormwater load was captured on this day. On October 16, 2002, the overnight portion of the storm was not monitored which resulted in a slightly lower portion of the load being captured (50 percent). Therefore, it appears that the stormdrain monitoring for the TMDL was capable of capturing approximately 50 percent of the stormwater loads from the Hampton Beach area. Small stormdrains and overland flow likely accounted for rest of the loading.

Tidal Flushing Model

The previous section was applicable to just the urban stormwater sources in the Hampton Beach area. It would be helpful to know the total stormwater load from all the sources both in the developed areas and in the less developed watersheds. The same model as was used to estimate the baseline dry weather non-point source loads (in Section 4(b)(ii)) can be used for this purpose as well. During wet weather, one new term is added to the model, k_{storm}, which signifies stormwater loads to the harbor. The equation for the model would then be:

Change in Storage = Sources - Sinks

$$\frac{\Delta(C \cdot V)}{\Delta t} = k_{storm} + k_b + k_w + k_d - C \cdot \frac{V_{TP}}{\Delta t} \cdot CF$$

Variable Definitions:
C = concentration of fecal coliform bacteria in the waterbody (MPN/100ml)
V = Estuary volume (gallons)
Δt = time step in increments of whole tidal cycles = 0.52 days
k_b = baseline load of NPS bacteria during dry weather conditions = 1,650 billion organisms per day (calculated in Section 4(b)(ii))
k_w = WWTF load = 0.3 billion organisms per day
k_d = Load from boat discharges = 238 billion organisms per day

k_{storm} = Stormwater load (billion organisms per day)
V_{TP} = Tidal exchange volume, equal to the difference between high tide and low tide volumes = 3.7 billion gallons (NAI, 1977)
CF = Conversion factor = 3.79E-08 (100ml*bill org)/(gallon*MPN)

Assuming steady-state conditions ($\Delta CV/\Delta t$=0), this equation reduces to a balance of sources and sinks.

$$Total\_Sources = k_{storm} + k_b + k_w + k_d = C \cdot \frac{V_{TP}}{\Delta t} \cdot CF = Total\_Sinks$$

which can be solved for k_{storm}:

$$k_{storm} = -k_b - k_w - k_d + C \cdot \frac{V_{TP}}{\Delta t} \cdot CF$$

The geomean FC concentrations in the harbor for different size storms can then be input for C to estimate the total stormwater load as shown in the following table:

Table 18: Modeled FC loads to Hampton/Seabrook Harbor during wet weather

Storm Size	Number of samples	Geomean (MPN/100ml)	Kstorm (bill org/day)
Dry (<0.01 in.)	662	7.023	0
0.02 to 0.50 in.	554	12.820	1,561
0.51 to 1.00 in.	289	19.129	3,260
>1.00 in.	166	29.167	5,964

Data Source: DES Shellfish Program, 1993-2002, all low tide data

The stormwater load predicted from this model is a combination of all sources (MS4 stormdrains, tributaries, overland flow). However, DES (2003a) only measured bacteria loads at 16 MS4 stormdrains and one tributary. On July 23, 2002, a load of 120 billion organisms per day was monitored from the 16 MS4 stormdrains combined, which is only 8 percent of the predicted load for a storm of this size (0.33 inches). Likewise on October 16, 2002, the total monitored load from the stormdrains was 630 billion organisms per day which was only 11 percent of the predicted total load for a 1.39 inch rainfall event. Therefore, the 16 MS4 stormdrains monitored by DES accounted for only approximately 10 percent of the total stormwater load predicted by the tidal flushing model.

<u>Summary of Modeled Stormwater Loads</u>

The two simple models used for this TMDL illustrate that the stormwater sources monitored for the TMDL were only a fraction (10 percent) of the total stormwater sources. In the developed Hampton Beach area, it appears that 50 percent of the bacteria loading sources were identified and monitored. Given that most of the TMDL monitoring effort was concentrated in this area, additional sampling is unlikely to produce a better capture rate. The uncaptured sources are probably diffuse overland flow or small pipes. For the watershed as a whole, the tidal flushing model predicts that only 10 percent of the MS4 sources were identified and monitored.

Therefore, contributions from other sources including tributaries and overland flow in the salt marshes are significant.

Both of the models used in this analysis are simplifications of a complex system and, therefore, have flaws. However, the purpose of this modeling exercise was to illustrate the relative strengths of the different bacteria sources based on the best available information. It is impossible to monitor diffuse bacteria loads from salt marshes and tributaries so models are a necessity.

For this TMDL, DES sought to document bacteria loads from stormwater sources to Hampton/Seabrook Harbor. Field sampling of loads from key MS4 stormdrains (Section 4(a)(ii)) and tributaries (Section 4(b)(iii)) provided information on the relative contributions of these sources. In addition, simple mass balance models were used to estimate the total load to the harbor. Since all sources were not monitored by the field sampling effort, it is not surprising that the modeled loads are significantly higher than the measured loads. The modeled loads are a better estimate of the total stormwater load to the harbor and will be used in the total load inventory in Section 4(c).

Stormwater will contain bacteria from both human and wildlife sources. The microbial source tracking data presented in Section 3(e) show that the ratio of human-related sources to wild animal sources during wet weather conditions is approximately 60:40. Therefore, the estimated stormwater loads from the model were split into human-related (human, pets, livestock) and wild animal (wildlife, avian) components using the same ratio.

Table 19 summarizes all the information on stormwater loads to the harbor.

Table 19: Summary of information on stormwater loads from human-related and wild animal sources

Source	Rainfall 0.02 to 0.50 in.		Rainfall 0.51 to 1.00 in.		Rainfall >1.00 in.		Comments
	Load*	Percent	Load*	Percent	Load*	Percent	
16 MS4 stormdrains	120	8%	NA	NA	630	11%	Monitored by DES on 7/23/02 (0.33 in. storm) and 10/16/02 (1.39 in. storm) (DES, 2003a)
Tributaries	68	4%	NA	NA	179	3%	The load from Mill Creek was monitored by DES on 7/23/02 (0.33 in. storm) and 10/16/02 (1.39 in. storm) (DES, 2003a). Loads from the other six tributaries were assumed to be equal to Mill Creek.
Other NPS stormwater	1,373	88%	3,260	100%	5,154	86%	Difference between model output and measured loads of MS4 stormdrains and tributaries.
Total	**1,561**		**3,260**		**5,964**		Estimated from tidal flushing model
Human-related bacteria load	937		1,956		3,578		Assumes 60% of bacteria in stormwater is human-related, based on results from Jones and Landry (2003).
Wild animal sourced load	624		1,304		2,385		Assumes 40% of bacteria in stormwater is from wild animals, based on results from Jones and Landry (2003).

** Bacteria load units are billion organisms per day*

c. Total Loading to Waterbody

Bacteria loads from the sources discussed in the previous sections are summarized in Table 20. The loading values in this table are estimates with considerable uncertainty, but they are useful to illustrate the relative magnitudes of the different sources of bacteria to the harbor.

Section A of Table 20 summarizes the daily bacteria loads from different sources during different rainfall amounts. The total load estimate ranges from 1,891 billion organisms per day for dry weather to 7,855 billion organisms per day for rainfall events greater than 1 inch of precipitation. The dominant source of bacteria to the harbor varies with rainfall condition. Under dry-weather conditions, dry-weather non-point source loads contribute 87 percent of the bacteria, followed by boat discharges (13 percent) (Figure 11). In contrast, during large rainstorms, stormwater sources dominate the bacteria loads (Figure 9). Overall, human sources are estimated to account for 61 to 65 percent of the bacteria under both wet and dry weather conditions.

Section B of Table 20 illustrates the average fecal coliform concentrations in the harbor during different rainfall conditions. Only during dry weather conditions do FC concentrations meet both components of the NSSP shellfishing standard (geomean <14 MPN/100ml, 90th percentile <43 MPN/100ml). Therefore, it can conservatively be assumed that only the bacteria load during dry weather (1,891 bill org/day) is acceptable for meeting water quality standards in the harbor.

Section C of Table 20 shows the total load of bacteria to the harbor over a full year. The daily loading rates for each rainfall condition were multiplied by the number of days that this condition is expected to occur (see Table 6 and Section B of Table 20) and then the products were summed. Over the course of a year, the largest source of bacteria to the harbor are dry weather non point sources (52 percent), followed by stormwater loads (41 percent), boat discharges (7 percent), and the Hampton WWTF (0.01 percent) (Figure 13). Although dry weather sources contribute the most bacteria to the harbor over a year, the clam flats in Hampton/Seabrook harbor are typically open during dry weather and closed during rainfall events, during which stormwater bacteria sources are dominant.

Estimates of bacteria loads from the Hampton WWTF in Table 20 are based on data on treated effluent from discharge monitoring reports. The loading estimate does not take into account loadings from the plant due to emergency bypasses of untreated or partially treated wastewater during storm events or other temporary and infrequent system failures.

Table 20: Summary of bacteria loads to Hampton/Seabrook Harbor

A. Summary of daily bacteria loads to Hampton/Seabrook Harbor under different rainfall conditions

Source	Bacteria Type	Rainfall Dry (<0.01 in.)	Rainfall 0.02 to 0.50 in.	Rainfall 0.51 to 1.00 in.	Rainfall >1.00 in.	Comments
Hampton WWTF	Human	0.30	0.30	0.30	0.30	From DMRs
	Wildlife	0	0	0	0	
Boat Discharges	Human	238	238	238	238	Estimated
	Wildlife	0	0	0	0	
Dry Weather Non-Point Sources	Human	992	992	992	992	Modeled
	Wildlife	661	661	661	661	Modeled
Stormwater Load	Human	0	937	1,956	3,578	Modeled
	Wildlife	0	624	1,304	2,385	Modeled
Total	Human	1,230	2,167	3,186	4,808	
	Wildlife	661	1,286	1,965	3,047	
	Total	**1,891**	**3,453**	**5,152**	**7,855**	

Bacteria load units are billion organisms per day

B. Summary of fecal coliform concentrations in Hampton/Seabrook Harbor under different rainfall conditions

Statistic	Rainfall Dry (<0.01 in.)	Rainfall 0.02 to 0.50 in.	Rainfall 0.51 to 1.00 in.	Rainfall >1.00 in.
Geometric mean concentration	7.02	12.82	19.13	29.17
90th percentile concentration	35.30	86.30	142.00	198.00
Percent of the year with this rainfall amount	55.3%	24.2%	10.9%	9.7%
Days per year with this rainfall amount	202	88	40	35

Fecal coliform concentrations in units of MPN/100ml.

C. Annual bacteria load to Hampton/Seabrook Harbor from different sources

Source	Rainfall Dry (<0.01 in.)	Rainfall 0.02 to 0.50 in.	Rainfall 0.51 to 1.00 in.	Rainfall >1.00 in.	**Total for the year**
Hampton WWTF	61	26	12	11	**110**
Boat Discharges	48,039	21,023	9,469	8,426	**86,957**
Dry Weather Non-Point Sources	333,682	146,024	65,771	58,530	**604,006**
Stormwater Load	0	137,905	129,715	211,141	**478,761**
Total	381,781	304,977	204,967	278,108	**1,169,834**

Bacteria load units are billion organisms per year
Annual load estimated by multiplying the daily load for different rainfalls by the number of days/yr when this condition occurs.

Figure 11: Percent of daily bacteria load from different sources during dry weather

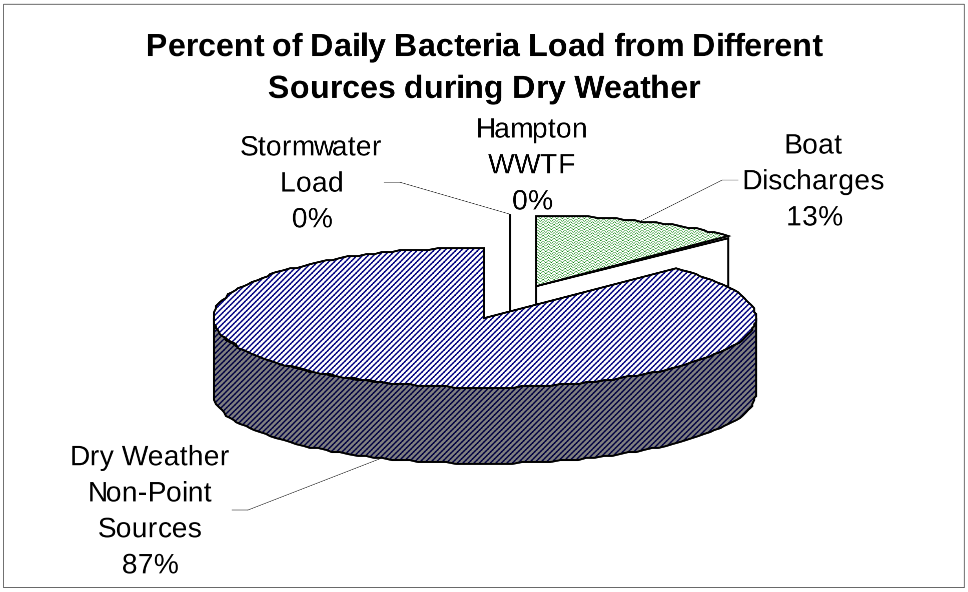


Figure 12: Percent of daily bacteria load from different sources during rainstorms (>1 in precipitation)

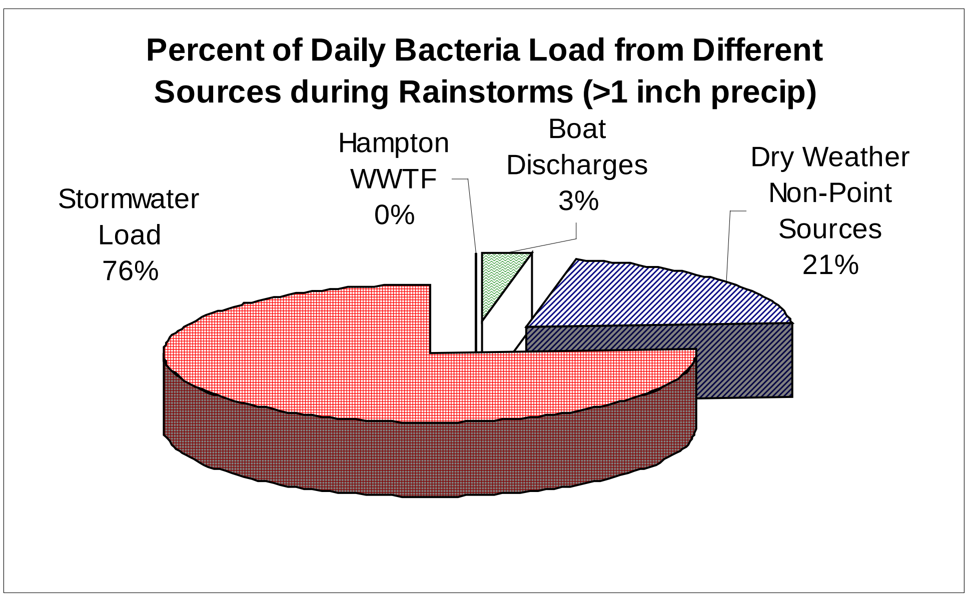
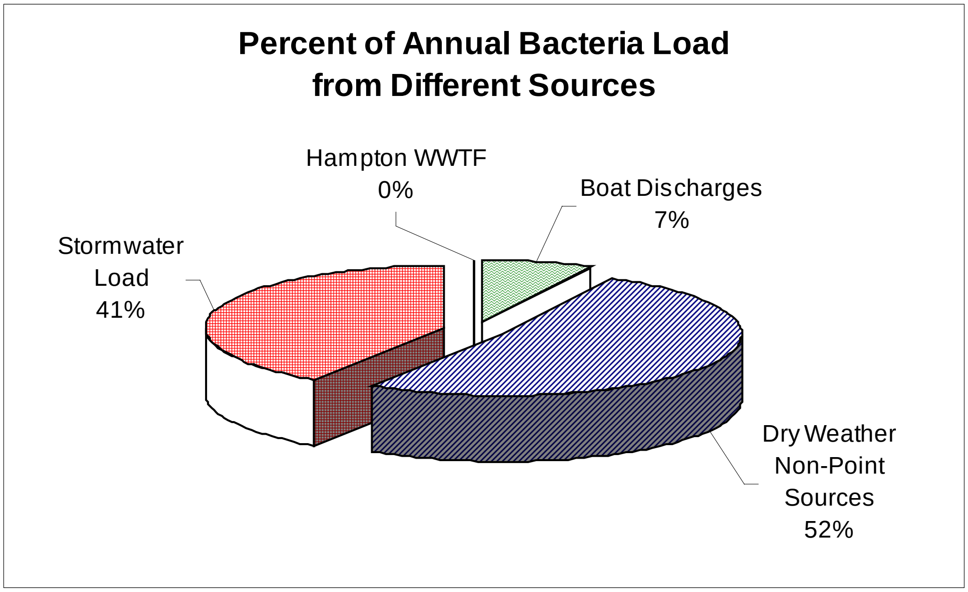


Figure 13: Percent of annual bacteria load from different sources



5. TMDL and Allocations

a. Definition of a TMDL

According to the 40 CFR Part 130.2, the total maximum daily load (TMDL) for a waterbody is equal to the sum of the individual loads from point sources (i.e., wasteload allocations or WLAs), and load allocations (LAs) from nonpoint sources (including natural background conditions). Section 303(d) of the CWA also states that the TMDL must be established at a level necessary to implement the applicable water quality standards with seasonal variations and a margin of safety (MOS) which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality.

In equation form, a TMDL may be expressed as follows:

$$TMDL = WLA + LA + MOS$$

where:

WLA = Waste Load Allocation (i.e. loadings from point sources)

LA = Load Allocation (i.e., loadings from nonpoint sources including natural background)

MOS = Margin of Safety

TMDLs can be expressed in terms of either mass per time, toxicity or other appropriate measure [40 CFR, Part 130.2 (i)]. The MOS can be either explicit or implicit. If an explicit MOS is used, a portion of the total allowable loading is actually allocated to the MOS. If the MOS is implicit, a specific value is not assigned to the MOS. Use of an implicit MOS is appropriate when assumptions used to develop the TMDL are believed to be so conservative that they are sufficient to account for the MOS.

b. Determination of TMDL (Loading Capacity)

i. Seasonal Considerations/Critical Conditions

NHF&G closes the flats each year for June, July, and August to preserve the resource. Harvesting would be allowed in all other months if the water quality standards were met. The standards are met during dry weather except in September and October, but not during wet weather. Therefore, the critical period for this TMDL should be wet weather periods between September through May and dry weather periods in September and October. Data from these critical periods were used to estimate the bacteria loads to the harbor. Therefore, the TMDL and percent reduction goals set by this study should result in attainment of the water quality standards during the critical periods.

ii. TMDL Calculation and Load Allocation

The TMDL calculation in Table 21 was conducted using the annual bacteria loads to the harbor from Table 20, Section C.

On the left side of Table 21, the existing bacteria loads to the harbor are listed as either point sources or non-point sources and then summed to a total annual load of 1,169,834 billion organisms per year. On the right side of the table, the TMDL, MOS, WLA, and LA are shown.

The TMDL was set at the annual load for dry weather conditions (1891.459 bill org/day * 365 day = 690,382 bill org/yr). As shown in Table 20, both the geomean and 90th percentile FC concentration standards are met during dry weather but not during wet weather when the loads are higher. Therefore, 1891 billion organisms per day can be conservatively assumed to be the acceptable daily FC load for the harbor, which is why this loading value was chosen for the TMDL.

The MOS was set at 10 percent of the TMDL (69,038 bill org/yr).

The WLA was set equal to TMDL-MOS multiplied by the ratio of total loads from point sources to total loads from non-point sources ((47,986/1,121,848)*(690,382-69,038)=26,577 bill org/yr). Within the WLA, 2,810 bill org/yr is allocated to the Hampton WWTF which has a maximum permitted load of 2,810 bill org/yr (7.7 bill org/day*365 day = 2,810 bill org/yr). This method of apportioning allocations is from EPA (2001b).

The LA was set equal to TMDL-MOS-WLA (690,382-69,038-26,577=594,767 bill org/yr).

iii. Margin of Safety

An explicit margin of safety equal to 10 percent of the TMDL was assumed to conservatively account for possible datagaps when setting the TMDL.

c. Load Reductions Needed to Achieve the TMDL

Table 21 shows the percent reduction calculation for this TMDL. The sum of the WLA and LA were compared to the total loading value to determine the percent reduction needed. Based on this calculation, a 47 percent reduction in total loading is needed to reach the TMDL. This value matches the percent reduction in 90th percentile FC concentrations in the harbor that is needed to comply with shellfishing water quality standards. On Table 22, the 90th percentile concentrations for all the NSSP stations in the harbor are compared to the NSSP standard minus a 10 percent margin of safety (43 MPN/100ml – 4.3 MPN/100ml=38.7 MPN/100ml). On average, 90th percentile FC concentrations need to be reduced by 35 percent in order to comply with NSSP standards. The reductions needed are not uniform in the harbor. The greatest percent reduction (65 percent) is needed in the area around HH19. The lowest percent reduction (4 percent) was calculated for station HH18.

The goal for this TMDL is for the bacteria concentrations throughout Hampton/Seabrook Harbor to meet all the water quality standards for shellfishing, primary contact recreation, and secondary contact recreation. Of these three designated uses, the water quality standards for shellfishing are the most stringent. Therefore, the targeted goal for this TMDL is for the water quality in Hampton/Seabrook Harbor to meet both aspects of the NSSP shellfishing standard (geomean and 90^{th} percentile concentrations) as measured in accordance with NSSP protocols. The 90^{th} percentile concentration is the NSSP shellfishing standard that is most out of compliance and requires the greatest percent reductions. It is expected that bacteria loading reductions needed to meet the NSSP standards will also cause primary and secondary contact recreation standards to be met. Follow-up monitoring, discussed in Section 6(b)(ii), will include measurements of both fecal coliforms and enterococci so that the water quality standards for all the designated uses can be assessed.

Table 21: TMDL Calculation

Bacteria TMDL Calculation for Hampton/Seabrook Harbor

		Existing Loads			TMDL Calculation				Percent Reduction Needed[8]
Location	**Source**	Point Sources[2]	Non-Point Sources[3]	Total Load	TMDL[4]	MOS[5]	WLA[6]	LA[7]	
Hampton Harbor	Hampton WWTF	110		1,169,834	690,382	69,038	26,577	594,767	47%
	Boat Discharges		86,957						
	Dry Weather Non-Point Sources		604,006						
	Stormwater Load	47,876	430,885						
	Total	47,986	1,121,848						

Notes
1. Bacteria loads expressed as billion organisms per year.
2. Ten percent of the total annual stormwater load from Table 20 (Section C) was considered "point sources" (478,761*0.1=47,876) because the 16 Phase II MS4 pipes accounted for 10% of estimated stormwater load on 7/23/02 and 10/16/02. The Annual WWTF load (110) was taken from Table 20 (Section C).
3. Annual loads from boat discharges and dry-weather non-point sources taken from Table 20 (Section C). Non-point source stormwater load calculated as the difference between the total annual stormwater load from Table 20, Section C (478,761) and the point-source stormwater load (47,876).
4. TMDL set at annual load for dry weather conditions in Table 20, Section A (1891.459 bill org/day * 365 day = 690,382 bill org/yr).
5. MOS set at 10% of the TMDL.

6. WLA set equal to TMDL-MOS multiplied by the ratio of total loads from point sources to total loads from non-point sources ((47,986/1,121,848)*(690,382-69,038)=26,577). Within the WLA, 2,810 bill org/yr is allocated to the Hampton WWTF which has a maximum permitted load of 2,810 bill org/yr (7.7 bill org/day*365 day = 2,810 bill org/yr). This method of apportioning allocations is from EPA (2001b).
7. LA set equal to TMDL-MOS-WLA.
8. Percent reduction calculated by 1-(WLA+LA)/Total Load.

Table 22: Percent reduction in concentrations needed to achieve the TMDL

Station	90th %ile FC Concentration	Target: TMDL minus MOS	Percent Reduction Needed
	(MPN/100ml)	(MPN/100ml)	(%)
HH10	48.4	38.7	20
HH11	52.6	38.7	26
HH12	78.8	38.7	51
HH17	77.6	38.7	50
HH18	40.3	38.7	4
HH19	109.4	38.7	65
HH1A	74.8	38.7	48
HH2B	68.8	38.7	44
HH5B	58.2	38.7	34
HH5C	44.3	38.7	13
Average	65	---	35
Min	40.3	---	4
Max	109.4	---	65

Data source: DES Shellfish Program data, 1993-2002, for all months except June-July-August, low tide samples (collected 3 hours before to 0.5 hours after dead low tide). Only routine samples collected with a systematic random design were used for the 90^{th} %ile calculation.

d. Supplemental Information on Load Reductions

The percent reduction goal calculated in the previous section will be the official goal of the TMDL and progress toward this goal will be evaluated using ongoing monitoring in accordance with NSSP protocols by the DES Shellfish Program. However, for implementation planning, some additional information would be helpful. For instance, managers should know how much of a load reduction is needed to achieve the water quality standards for different size storms. Likewise, it would be useful to know the largest size storm for which the total load from natural sources would still be acceptable (e.g., would not cause exceedences of the standards). The estimated loading values from Table 20 can be used to derive answers to these important questions.

In Section 4(c), the total FC load to the harbor during dry weather conditions was estimated to be 1891 billion organisms per day. As shown in Table 20, both the geomean and 90th percentile FC concentration standards are met during dry weather but not during wet weather when the loads are higher. Therefore, 1891 billion organisms per day can be conservatively assumed to be the acceptable total FC load for the harbor. In order to reduce the loading during wet weather periods to the dry weather level, the wet weather loads would have to be reduced by 45 percent for 0.02-0.50 inch storms ((3453-1891)/3453), 63 percent for 0.51-1.0 inch storms ((5152-1891)/5152), and 76 percent for >1.0 inch storms ((7855-1891)/7855) (see Table 20 Section A). Reductions of this magnitude may not be feasible for larger storms. If only human sources can be controlled, the human sources would have to be cut by 72 percent for 0.02-0.50 inch storms ((3453-1891)/2167) and approximately 100 percent 0.51-1.0 inch storms ((5,152-1,891)/3,186) (see Table 20 Section A). For storms of greater than 1 inch of precipitation, the wildlife load (3,047 bill org/day) is greater than the total load for dry weather conditions (1,891 bill org/day). Therefore, reducing wet weather loads to dry weather levels does not appear to be feasible for storms with more than approximately one inch of precipitation without somehow reducing the wildlife load.

6. Implementation Plan

a. Statutory/Regulatory Requirements

Section 303(d)(1)(C) of the CWA provides that TMDLs must be established at a level necessary to implement the applicable water quality standard. The following is a description of activities that are planned to abate water quality concerns in Hampton/Seabrook Harbor.

b. Description of Activities to Achieve the TMDL

i. Implementation Plan

<u>Approach</u>

The objective of the implementation plan is to remove all human sources of bacteria to the estuary to the extent practicable. A phased and iterative approach will be used. Follow-up monitoring both in the harbor and at specific sources will be conducted to evaluate the effectiveness of remedial actions, to identify any new sources, and to characterize public health risks from primary contact recreation exposure to undiluted stormwater.

DES will work with the towns of Hampton and Seabrook to develop specific projects to reduce human-related bacteria loads to the estuary. Preliminary ideas for implementation actions are listed below. DES staff met with public works and conservation officials from Hampton and Seabrook in April 2003 to initiate a discussion of these ideas and other means of effectively reducing bacteria loads. Specific action items for this implementation plan will be developed collaboratively with the towns following the public comment period for this TMDL. Implementation of action items will depend upon the availability of funds.

<u>Preliminary List of Implementation Projects</u>

- Use wet-weather loading data from the TMDL study to prioritize stormdrains for remedial measures.
- Eliminate any illicit connections to stormdrains that are discovered.
- Promote nonstructural best management practices (such as street sweeping, pet waste ordinances, and catch basin stenciling) in areas with stormwater drainage infrastructure.
- Assist EPA in implementing Federal Storm Water Program Phase II MS4 General Permit regulations.
- Promote and expand boat sewage pumpout facilities.
- Pursue a “No Discharge Area” designation for the New Hampshire coast.
- Promote public education about septic system maintenance.
- Conduct a shoreline survey of Mill Creek to identify bacteria sources.
- Implement recommendations of NHEP/UNH study of untreated or partially treated wastewater discharges due to runoff-induced hydraulic overloading or exfiltration from aging sewer infrastructure. (Report with recommendations due December 2003.)
- Develop more accurate measurements of bacteria loads from tidal tributaries.

ii. Monitoring

Data from routine monitoring conducted in accordance with NSSP protocols by the DES Shellfish Program will be used to assess progress toward the goals of this TMDL and compliance with water quality standards for shellfishing.

As part of the EPA-funded National Coastal Assessment, enterococci concentrations are monitored at four stations in the middle of the harbor between April and December on a monthly frequency. Data from this monitoring program will be used to assess progress toward the goals of this TMDL and compliance with water quality standards for primary and secondary contact recreation.

The Water Quality Section of the DES Watershed Management Bureau will collect samples of stormwater and near-shore waters near stormdrains to be analyzed for enterococci to characterize public health risks from exposure. This study will target stormdrains that are easily accessible and are located near areas frequented by people.

Individual restoration actions to remove bacteria sources may involve before and after monitoring to document the loading reduction achieved.

7. Public Participation

a. Description of the Public Participation Process

DES staff have worked closely with officials from the towns of Hampton and Seabrook during the TMDL development. The following is a list of the interactions between the towns and the State during the TMDL development.

Table 23: State-Town interactions during the TMDL development

Date	Participants	Purpose
5/12/02	DES and Seabrook DPW officials	To explain the TMDL process and solicit information on stormwater infrastructure
5/12/02	DES and Hampton DPW officials	
7/23/02	DES and Seabrook DPW officials	Notification of DES stormwater sampling event
7/23/02	DES and Hampton DPW officials	
10/16/02	DES and Seabrook DPW officials	Notification of DES stormwater sampling event
10/16/02	DES and Hampton DPW officials	
4/21/03	DES and Seabrook Sewer Department	To present the results of the microbial source tracking (Jones and Landry, 2003) and Hampton/Seabrook Harbor TMDL studies and to solicit ideas for reducing bacteria loads to the harbor
4/21/03	DES and Seabrook Conservation Commission	
4/22/03	DES and Hampton DPW officials	
4/22/03	DES and Hampton Conservation Commission	
4/28/03	DES and Seabrook DPW and Seabrook WWTF	

EPA regulations [40 CFR 130.7(c)(ii)] requires that calculations to establish TMDLs be subject to public review. In accordance with this requirement, a public comment draft was distributed on May 28, 2003 to the three towns abutting the harbor: Hampton, Seabrook, and Hampton Falls. At the same time, the report was posted on the DES website: www.des.state.nh.us/wmb/TMDL/. Notices about the report were run in the Portsmouth Herald, the Hampton Union, and the Fosters Daily Democrat newspapers on Sunday, June 1, 2003. Finally, the New Hampshire Estuaries Project and New Hampshire Coastal Program broadcast notices about the report to their email lists (68 addresses total). The public comment period lasted for 60 days (June 1 to August 1, 2003).

b. Public Comment and DES Response

DES did not receive any comments from the public on the draft report.

8. References

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Jones SH (2003) Tracking Bacterial Pollution Sources in Stormwater Pipes. A final report to the New Hampshire Estuaries Project/Office of State Planning. University of New Hampshire, Jackson Estuarine Laboratory, Durham, NH. April 2003.

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USGS/DES (2002) Assessment of Environmental Factors Affecting Fecal Coliform Concentrations in Hampton/Seabrook Harbor, New Hampshire, 2000-01. WRIR 02-4252. US Department of the Interior, US Geological Survey, Pembroke NH in cooperation with the New Hampshire Department of Environmental Services, Concord NH. 2002.

APPENDIX A

Figures 4 and 5 from QA Project Plan (DES, 2002b)

Figure 4: Stormwater pipes and tributary stations for wet-weather monitoring.

The labeled pipes and tributary stations will be part of the wet-weather monitoring program for the TMDL.

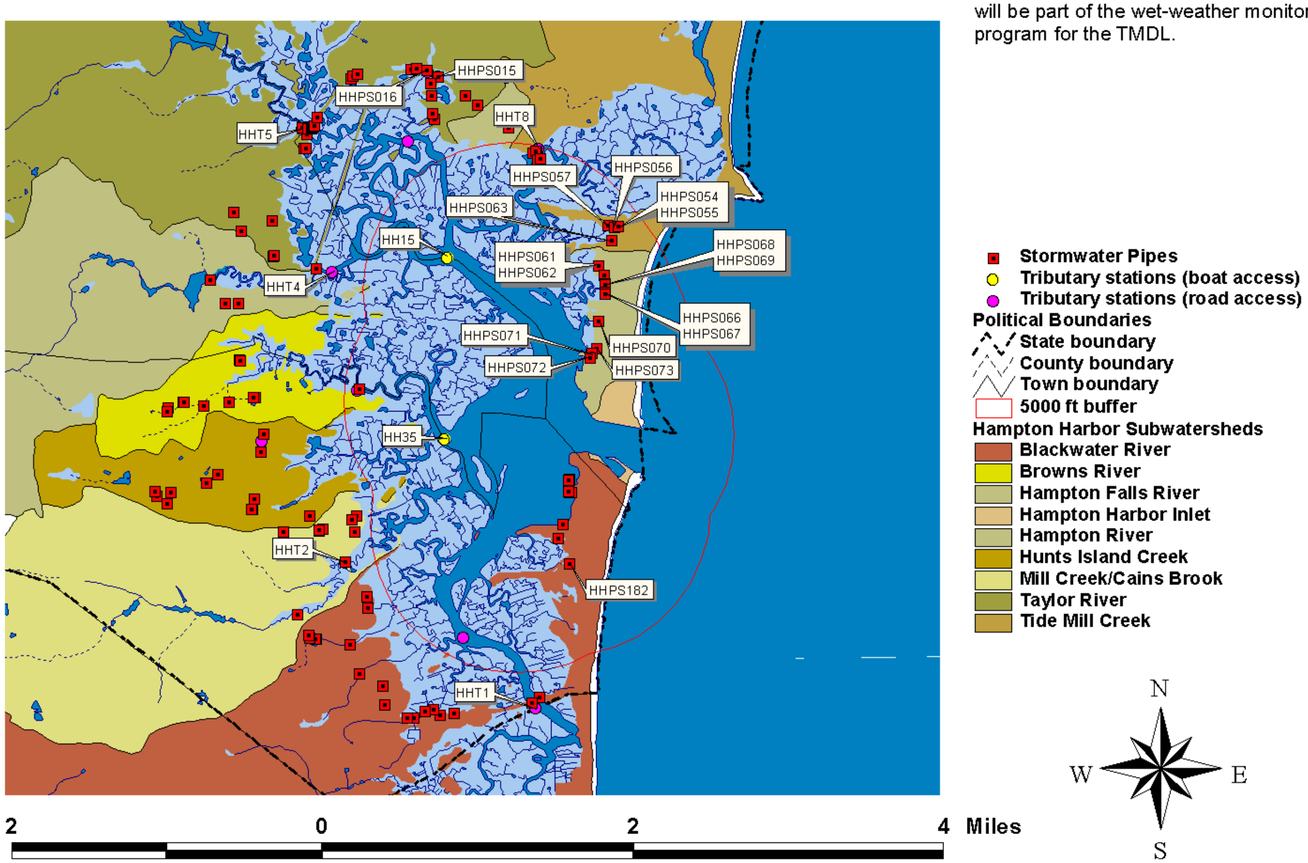
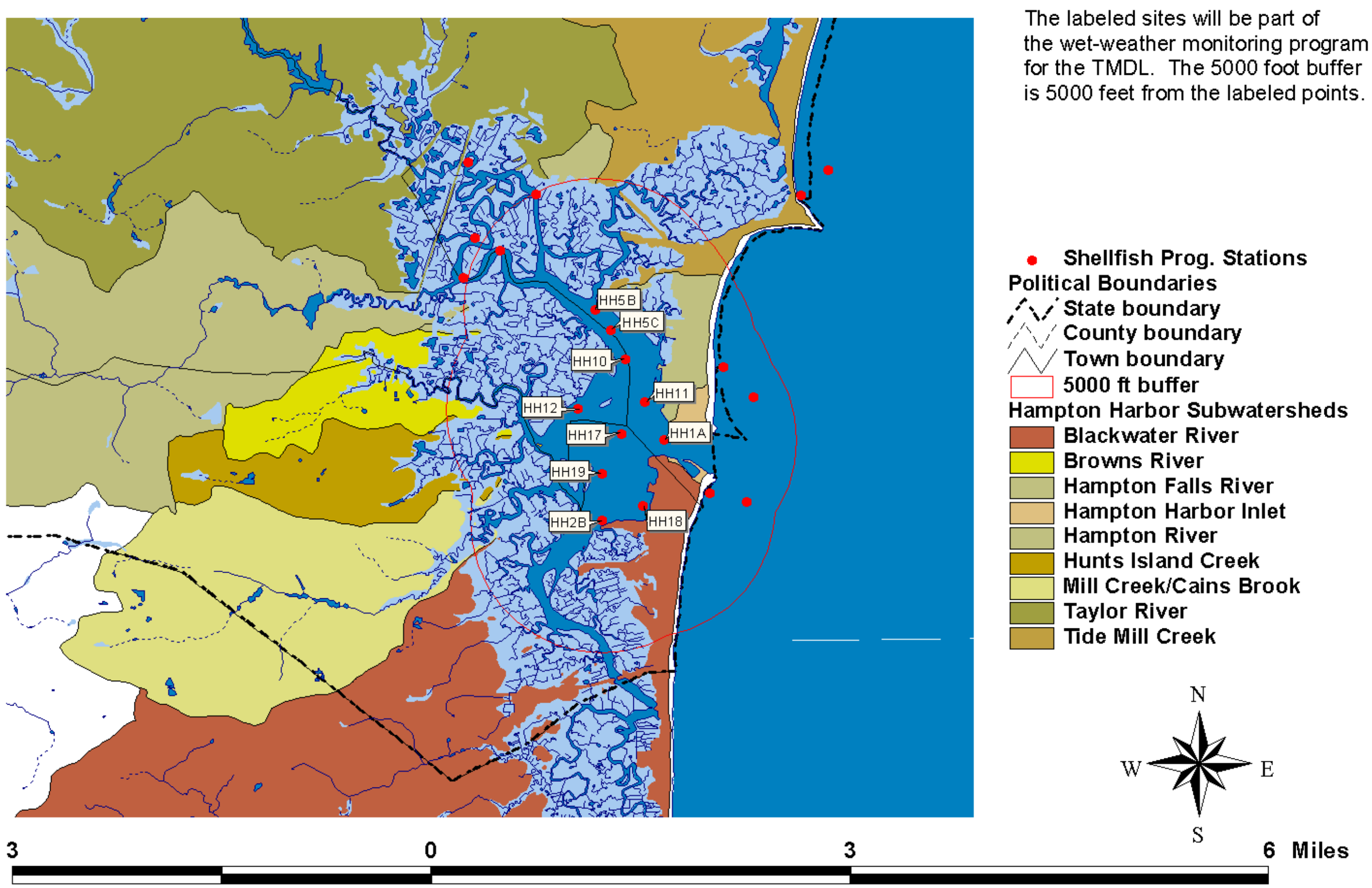


Figure 5: DES Shellfish Program Stations in Hampton Harbor.



APPENDIX B

Data from DES Stormwater Sampling Program 2002 (DES, 2003a)

FIELD EVALUATION OF WET WEATHER BACTERIA LOADING IN HAMPTON/SEABROOK HARBOR

Work to Support the Development of a Bacteria TMDL

Workplan Number 01-A-10.1

A Final Report to

The New Hampshire Estuaries Project

Submitted by

Phil Trowbridge
N.H. Department of Environmental Services
Watershed Management Bureau
6 Hazen Drive
Concord, NH 03301

January 14, 2003

This report was funded in part by a grant from the Office of State Planning, New Hampshire Estuaries Project, as authorized by the U.S. Environmental Protection Agency pursuant to Section 320 of the Clean Water Act.

New Hampshire Estuaries Project

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Executive Summary

During 2002, in and around Hampton Harbor, the New Hampshire Department of Environmental Services (DES) conducted two rounds of wet weather sampling of stormdrains, tributaries, and harbor stations for bacteria and flow in order to calculate bacteria loads. This information was needed to prioritize pollution sources as part of a Total Maximum Daily Load (TMDL) study of bacteria in Hampton/Seabrook Harbor.

Introduction

Over the past several years, DES and other agencies have focused a significant effort on identifying pollution sources that contribute to wet weather contamination of Hampton/Seabrook Harbor (hereafter "Hampton Harbor"). The goal of these efforts has been to accurately identify and ultimately eliminate these sources, which contribute to the restrictions on shellfish harvesting that have been in place since 1994. The DES Shellfish Program has identified and sampled approximately 100 sources of stormwater to the estuary. The DES Watershed Assistance Section will soon have funding to address these types of sources. However, these funds can only be used for corrective actions in waterbodies for which a Total Maximum Daily Load (TMDL) has been developed.

DES has proposed the development of a bacterial TMDL for Hampton Harbor, targeted on wet weather sources of contamination. Full TMDL development generally consists of the following steps:

- Problem identification
- Identification of water quality indicators and targets
- Source assessment
- Linkage between water quality targets and sources
- Allocations
- Follow-up monitoring and evaluation
- Assembling the TMDL

The development of the above steps will be largely be completed by existing DES staff without NHEP funding. However, it was determined that the quality of the TMDL would be greatly enhanced with a better assessment of pollution source loadings. Thus, funding from the NHEP was solicited to enhance the "Source Assessment" step; specifically, enhancing the existing data on stormwater sources through targeted monitoring and discharge estimation. Before this study, data on these sources consisted of one sample per pipe from three different storm events, with no data on pipe discharge. To properly quantify bacterial loading from these sources, it was necessary to collect several samples from each source during the same storm, along with concurrent estimations of discharge. This more detailed evaluation of loading enabled a more accurate linkage between water quality targets and sources, enhanced the source allocations developed, and will ultimately lead to a rigorous process for targeting restoration funds on the most significant sources of bacteria.

Project Goals and Objectives

The goal of this project is to monitor the bacteria loads from the highest priority stormwater pipes or conveyances near the shellfish growing areas in Hampton Harbor. Specific objectives are to:

- Select sites for loading measurements
- Monitor bacteria concentrations and flow at selected sites during 2-3 storms of >0.25 inch total precipitation
- Analyze water samples for bacteria concentrations
- Manage and analyze the data from the study

Methods

Storm Selection

For this study, two or three storms were needed with the following characteristics: (1) Onset at or around low tide; (2) >0.25 inches total precipitation; (3) occurrence during daylight hours on Monday-Thursday; and (4) very little rainfall for the prior three days. These criteria were met for the two storms that DES used for this study.

The first storm on July 23, 2002 was a short, but intense rainstorm that dropped 0.33 inches of precipitation over 4 hours (precipitation measured at Seabrook Station). The second storm on October 16, 2002 was a classic "Nor'easter" with soaking rain and high winds lasting over 12 hours. A total of 1.39 inches of rain fell during the second storm. Since these two storms were so different, the monitoring results from each day probably bracket the range of possible loadings. Both rainstorms coincided with a low tide as shown in the following table. Figures 1, 2, and 3 are radar images of precipitation from the storms.

Table 1: Total precipitation, tides, and sampling times for monitored storms

Date	Precip (in)	Low Tide Portland ME	Low Tide Hampton NH	Low Tide Height* (ft)	First Samples Collected	Last Samples Collected
7/23/02	0.33	17:10	17:55	0.7	14:29	19:20
10/16/02	1.39	14:40	15:25	1.3	09:40	16:50

* At Portland ME

Figure 1: The approaching storm on 10/16/02 at 07:25 local time

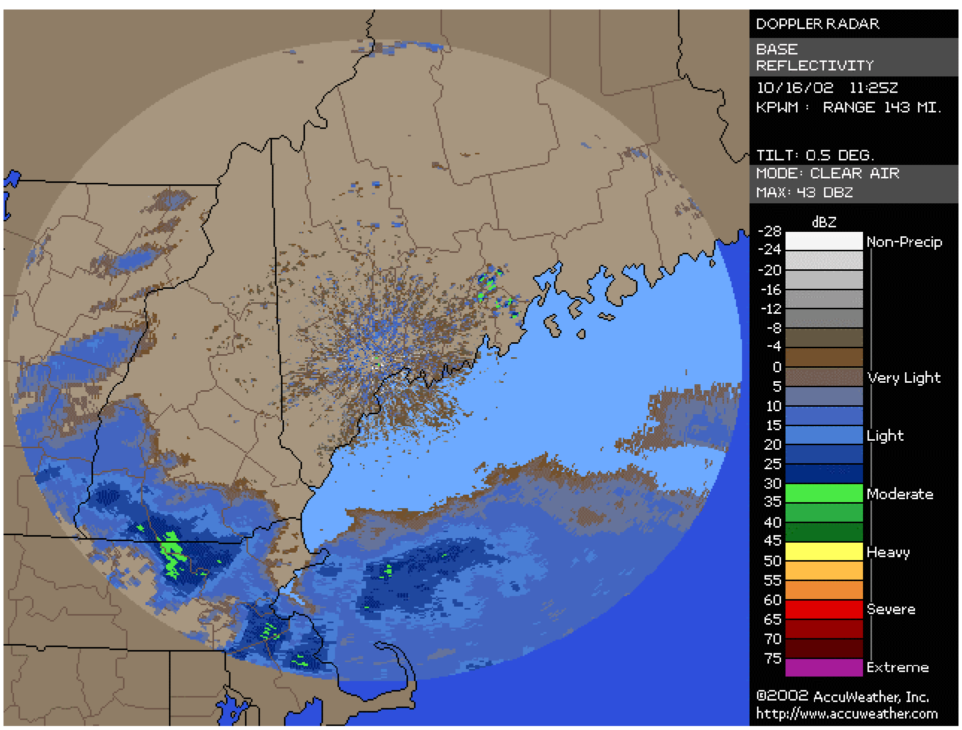


Figure 2: 24 hour precipitation totals for the storm on 7/23/02

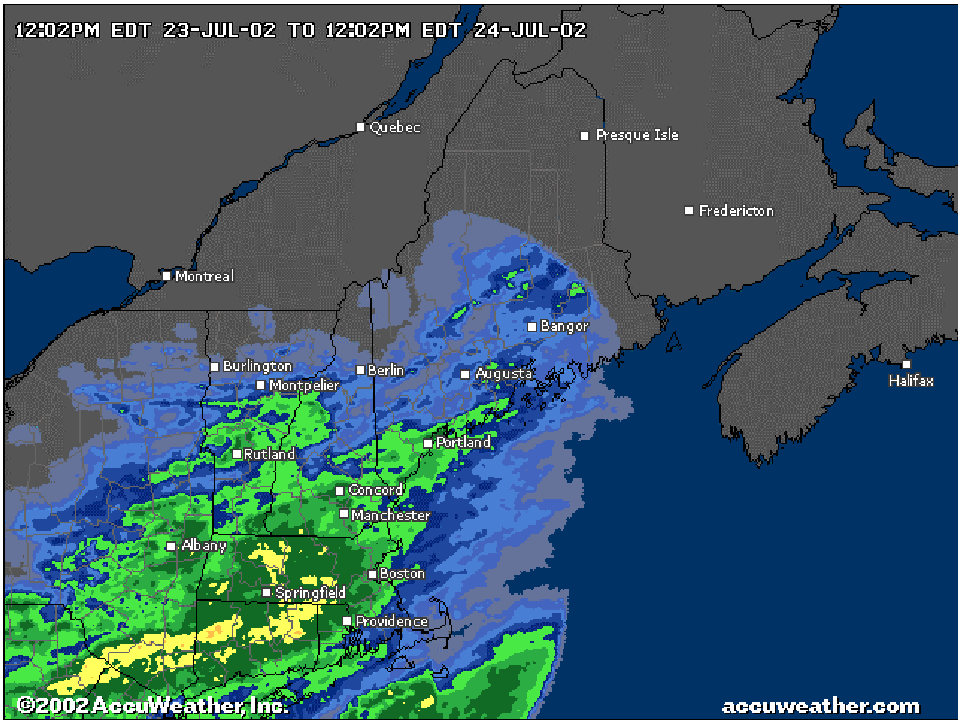
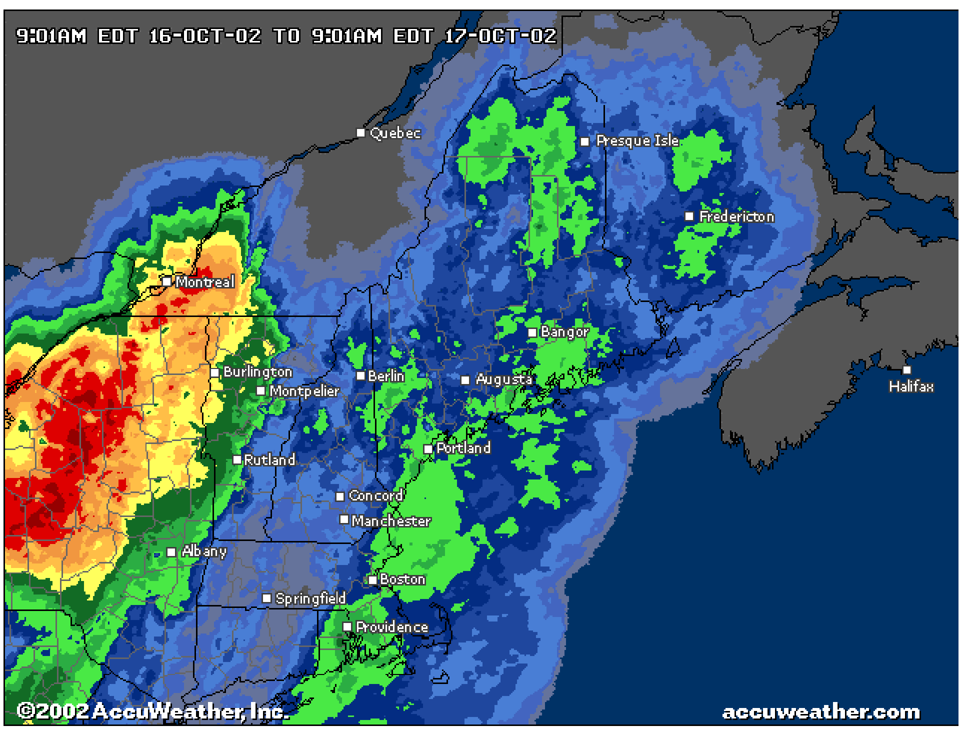
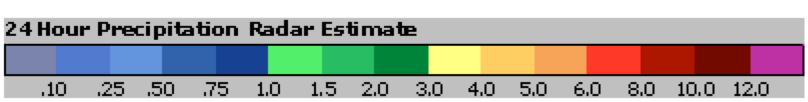


Figure 3: 24 hour precipitation totals for the storm on 10/16/02



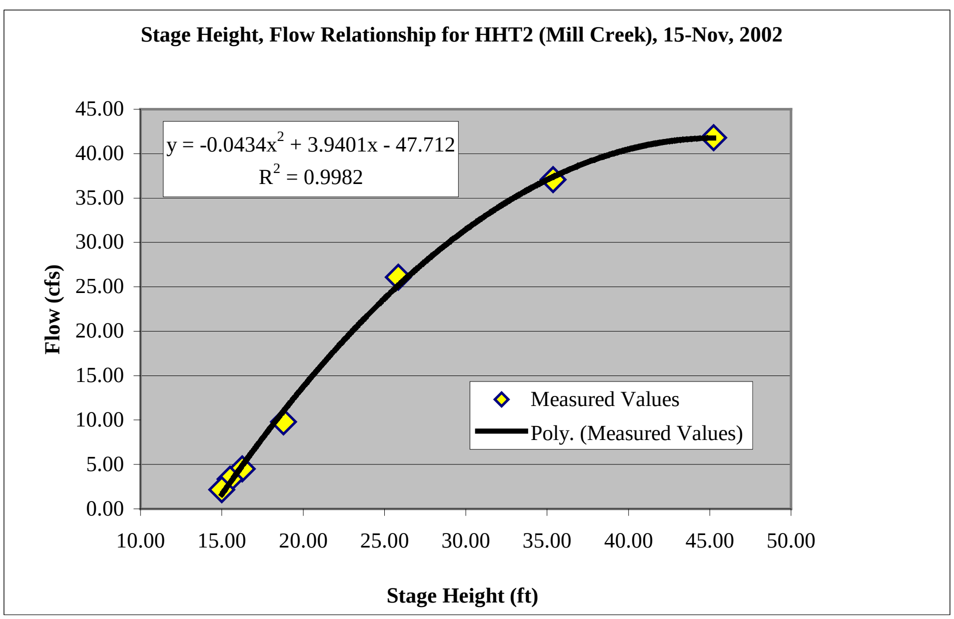


Station Selection and Field Methods

The sampling locations, methods, and data analysis procedures for this study are described in detail in the approved QA Project Plan, which is included as Appendix B to this report. The only portions of the study that are not covered by the QA Project Plan are: (1) Establishment of a stage-height/flow relationship for Mill Creek; and (2) flow estimates for HHPS182 . The methods used for these tasks are described below.

The flow through Mill Creek was needed in order to estimate the bacteria load from the tributary. During storms, the field teams did not have time to measure the flow directly because this would involve a 30 minute river traverse. Instead, a graduated pole was installed in the river near HHT2 on 5/30/02. Field teams recorded the height of water on the pole when they collected samples during the storms on 7/23/02 and 10/16/02. On 11/15/02, DES staff returned to HHT2 and measured the flow in the creek at seven different times during the falling tide. The tidal range on 11/15/02 (low tide height 1.2 ft.) was similar to the range that occurred on 7/23/02 and 10/16/02 (low tide height 0.7-1.3 ft.). DES Standard Operation Procedures for stream flow measurements were used (Appendix C). A quadratic relationship was developed between the flow and the water height on the graduated pole. This relationship was then used to estimate the flow at HHT2 at the time samples were collected during the two storms from the records of water height. The graduated pole was removed on 11/15/02 after the study was complete. The following figure illustrates the relationship between stage height and flow that was developed.

Figure 4: Stage height/flow relationship for HHT2



HHPS182 has two large culverts that are sealed with "duckbill" tide gates. The duckbills prevent measurements of flow in the culverts. However, the northern pipe receives most of its flow from two pump stations (River Street and Ocean Blvd stations). Therefore, total flow from this pipe was estimated from the hours that each pump ran during the storm multiplied by the pump rate. The running time for each pump during the storms was provided by the Seabrook Department of Public Works. The southern pipe at HHPS182 drains a smaller area than the northern pipe and is not associated with any pump stations. Assuming the runoff characteristics of the land are uniform, the flow from the southern pipe was estimated using flow from the northern pipe and the ratio of the area drained by the southern pipe to the area drained by the northern pipe (approx. 0.4). Table D4 in Appendix D contains the flow summaries for HHPS182.

Results and Discussion

The following tables summarize the monitoring data from stormdrains, tributaries, and harbor stations. Stormdrain results are presented as the total load of fecal coliform bacteria discharged from the source over the course of the storm. The results for tributaries are presented as mean concentrations during the two storms with the exception of HHT2 for which loads were also calculated. The table summarizing the harbor stations contains the raw measurements. Raw data for flow and fecal coliform concentrations are presented in Appendix D. For maps of station locations, refer to Figures 4 and 5 of the QA Project Plan (Appendix B). All measurements have passed the QA review specified in the QA Project Plan.

Stormwater from Stormdrains

Loads from the stormdrains monitored for this project are summarized in the following table. The data and any assumptions used for these calculations are shown in Table D5 in Appendix D.

Table 2: Summary of bacteria loads from stormdrain sources

Source	Bacteria Load (7/23/02) 0.33” precip	Bacteria Load (10/16/02) 1.39” precip	Percent of Total Load (7/23/02)	Percent of Total Load (10/16/02)	Comments
	(bill org)	(bill org)	(%)	(%)	
Loading from Stormdrains					
HHPS061	no info	0.0		0%	No Flow
HHPS062	no info	4.1		1%	
HHPS073	no info	0.0		0%	No Flow
HHPS072	5.2	7.7	4%	1%	
HHPS071	0.6	4.7	0%	1%	
HHPS070	0.2	14.7	0%	2%	
HHPS054	0.0	0.0	0%	0%	No Flow
HHPS055/056	0.0	5.0	0%	1%	No Flow 7/23
HHPS057	0.0	0.0	0%	0%	No Flow
HHPS015	1.7	10.8	1%	2%	
HHPS016	11.1	138.4	9%	22%	
HHPS066	13.9	67.0	12%	11%	
HHPS067	1.1	10.0	1%	2%	
HHPS068	0.1	24.0	0%	4%	
HHPS069	14.2	98.2	12%	16%	
HHPS182	71.8	245.7	60%	39%	
Subtotal	**119.8**	**630.3**	**100%**	**100%**	

The results of the DES stormwater sampling show that the loading from monitored stormdrain sources was approximately 120 billion organisms during the storm on 7/23/02 and 630 billion organisms on 10/16/02. The source with the greatest individual loading (39-60% of the total) was HHPS182 which drains most of the Seabrook Beach area. The four stormdrains behind the Hampton Police Department (HHPS066, HHPS067, HHPS068, and HHPS069) collectively accounted for 25-33% of the monitored loads.

Stormwater from Tributaries

In addition to monitoring loading from stormdrains, the seven major tributaries to the harbor were sampled during the storms. Using a stage discharge relationship, it was possible to estimate flow (and, therefore, load) from one of the tributaries, Mill Creek. This tributary consistently had the highest concentrations of fecal coliforms. The results of the monitoring is shown in the table below.

Table 3: Summary of fecal coliform concentrations in wet weather tributary samples

Tributary	Station	N (7/23/02)	Mean FC Conc. (7/23/02)	FC Load (7/23/02)	N (10/16/02)	Mean FC Conc. (10/16/02)	Conc. (10/17/02) (n=1)	FC Load (10/16/02)
		(#)	(cfu/100ml)	(bill org)	(#)	(cfu/100ml)	(cfu/100ml)	(bill org)
Blackwater River	HHT1	4	50	NA	5	41	40	NA
Mill Creek	HHT2	4	500	9.75	5	412	1960	25.60
Hampton Falls River	HHT4	4	88	NA	5	107	30	NA
Taylor River	HHT5	4	125	NA	5	22	980	NA
Browns River	HH35	3	22	NA	1	10	20	NA
Hampton River	HH15	3	10	NA	1	<10	40	NA
Tide Mill Creek	HHT8	3	67	NA	5	82	30	NA

Mean values calculated using 1/2 the method detection limit (MDL) for samples reported as "<MDL" and the value for samples reported as ">value".

The tributary sampling showed that the highest concentrations were in Mill Creek (HHT2). This pattern matches the observation that the highest fecal coliform concentrations among the harbor stations is at HH19 at the mouth of Mill Creek (see next section).

The loading from Mill Creek during the two storms ranged from 10 to 26 billion organisms. These loading estimates are probably lower than the actual load from this tributary because the station was only monitored during the storm and runoff from the watershed would have continued for hours or days after the storm.

Stormwater Effects on Harbor Water Quality

During the two TMDL sampling events, ten stations in the middle of the harbor were monitored before and after the storm. The goal was to document the immediate effect of stormwater loads on the ambient harbor water quality. Results from the harbor station sampling are shown in the following table.

Table 4: Fecal coliform concentrations in Hampton Harbor during TMDL sampling storms

	HH10	HH11	HH12	HH17	HH18	HH19	HH1A	HH2B	HH5B	HH5C	Geomean of All Stations
7/23/02 Pre-storm	10	10	10	10	10	10	10	10	10	5	9.33
7/23/02 Storm 1*	10	10	10	10	5	10	40	10	10	10	10.72
7/23/02 Storm 2*	10	10	30	10	10	20	10	10	10	10	11.96
10/16/02 Pre-storm	10	10	10	40	10	10	10	30	10	10	12.82
10/17/02 Post-storm	10	10	10	30	30	80	10	10	10	30	17.12

* "Storm 1" and "Storm 2" samples on 7/23/02 were collected during the storm.

During both storms, the geomean fecal coliform concentration across all the stations increased 28 - 34% from pre-storm conditions to post-storm conditions. However, these apparent increases were not statistically significant as tested using the Wilcoxon Signed Ranks Test for dependent samples. The only large jump in fecal coliform concentrations was at the mouth of Mill Creek (HH19) between 10/16/02 and 10/17/02. The fecal coliform concentration started at 10 cfu/100ml before the storm and ended at 80 cfu/100ml after the storm. The second reading was the only measurement in the harbor greater than 43 cfu/100ml during the TMDL sampling events. This observation is consistent with the data presented above showing higher fecal coliform concentrations in Mill Creek than in other tributaries.

Conclusions

The results of this study provide insight into the relative magnitude of known sources of bacteria to Hampton Harbor.

Recommendations

The data collected for this study should be used to develop the bacteria TMDL for Hampton Harbor.

Appendices

Appendix A

Budget and Expenditures

Class	Expenditure	NHEP funds Received	NHEP funds Spent	Balance of NHEP funds	NHEP funds to be applied to Little Harbor TMDL	NHEP funds to be repro-grammed
020	Supplies	$1,000	$1,000	$0	$0	$0
030	Equipment	$2,000	$1,418	$582	$582	$0
049	Lab analyses	$11,220	$4,080	$7,140	$2,500	$4,640
050	Overtime/Intern	$1,100	$0	$1,100	$1,100	$0
070	In-State Travel	$200	$0	$200	$0	$200
Total		$15,520	$6,498	$9,022	$4,182	$4,840

Note: $1,230 was amended to the NHEP contract with Great Bay Coast Watch for assistance with the HH TMDL. Since these funds were not included in the DES contract, they do not appear on this table.

Appendix B

Quality Assurance Project Plan

Wet-Weather Bacterial Loading for Hampton Harbor TMDL
Quality Assurance Project Plan

Revision 3 - FINAL

June 20, 2002

Prepared by
Phil Trowbridge
NH Department of Environmental Services
Watershed Management Bureau

Project Manager: ______________________________
Signature / Date
Phil Trowbridge, NHDES

Project QA Officer: ______________________________
Signature / Date
Peg Foss, NHDES

Program Manager: ______________________________
Signature / Date
Gregg Comstock, NHDES

Laboratory Quality Assurance Officer: ______________________________
Signature / Date
Rachel Rainey, NHDES

NHDES Quality Assurance Manager: ______________________________
Signature / Date
Vincent Perelli, NHDES

USEPA NEP Project Manager: ______________________________
Signature / Date
Jean Brochi, US EPA Region I

USEPA TMDL Project Manager: ______________________________
Signature / Date
Alison Simcox, US EPA Region I

USEPA Quality Assurance Manager: ______________________________
Signature / Date
Arthur Clark, US EPA Region I

A2 – Table of Contents

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A3 – Distribution List

Table 1 presents a list of people who will receive the approved QAPP, the QAPP revisions, and any amendments.

Table 1. QAPP Distribution List

QAPP Recipient Name	Project Role	Organization	Telephone number and Email address
Phil Trowbridge	Project Manager	NHDES Watershed Management Bureau	603-271-8872 603-661-7561 (mobile) ptrowbridge@des.state.nh.us
Peg Foss	Project QA Officer	NHDES Watershed Management Bureau	603-271-5448 mfoss@des.state.nh.us
Gregg Comstock	Program Manager	NHDES Watershed Management Bureau	603-271-2983 gcomstock@des.state.nh.us
Rachel Rainey	Laboratory QA Officer	NHDES Laboratory	603-271-2993 rrainey@des.state.nh.us
Andrea Donlon	Program QA Coordinator	NHDES Watershed Management Bureau	603-271-8862 adonlon@des.state.nh.us
Vincent Perelli	NHDES Quality Assurance Manager	NH DES Planning Unit	603-271-8989 vperelli@des.state.nh.us
Chris Nash	Field Sampling Coordinator	NHDES Watershed Management Bureau	603-430-7900 cnash@des.state.nh.us
Andy Chapman	Field Sampling Team Leader	NHDES Watershed Management Bureau	603-430-4078 achapman@des.state.nh.us
Natalie Landry	Field Sampling Team Leader	NHDES Watershed Management Bureau	603-433-0877 nlandry@des.state.nh.us
Matthew A. Wood	Field Sampling Team Leader	NHDES Watershed Management Bureau	603-271-8475 mwood@des.state.nh.us
Rob Livingston	Field Sampling Team Leader	NHDES Watershed Management Bureau	603-271-3398 rlivingston@des.state.nh.us
Ann Reid	Volunteer Coordinator	Great Bay Coast Watch	603-749-1565 ann.reid@unh.edu
Jean Brochi	EPA Project Officer (National Estuary Program)	EPA New England	617-918-1536 brochi.jean@epa.gov
Alison Simcox	EPA Project Officer (TMDL Program)	EPA New England	617-918-1684 simcox.alison@epa.gov
Arthur Clark	USEPA Quality Assurance Officer	USEPA New England	617-918-8374 Clark.Arthur@epamail.epa.gov

Based on EPA-NE Worksheet #3

A4 – Project/Task Organization

This study will be completed by staff from NHDES Watershed Management Bureau with sampling assistance from Great Bay Coast Watch volunteers and laboratory analysis by the NHDES Laboratory.

NHDES Watershed Management Bureau

Phil Trowbridge, the N.H. Estuaries Project Coastal Scientist, will be the Project Manager, under the supervision of Gregg Comstock, supervisor of NHDES' Water Quality Planning Section. The Project Manager will be responsible for the overall completion of the project, preparation of the final report, preparation and maintenance of the approved QA Project Plan, and will be the primary contact between NHDES and EPA.

Peg Foss the TMDL Coordinator for the NHDES Water Quality Planning Section will act as the Project QA Officer.

Chris Nash, Supervisor of the NHDES Shellfish Program, will be responsible for deciding when to mobilize the field sampling effort, coordinating field sampling activities, and coordinating sample delivery to the laboratory. Chris Nash will notify Phil Trowbridge when a favorable storm is predicted. Phil Trowbridge will notify all members of the sampling teams by email to hold the date. As the storm nears, Chris Nash will update Phil Trowbridge regarding the suitability of the storm and Phil Trowbridge will keep the rest of the sampling crews informed. The final decision on whether to mobilize the crews will be made by Chris Nash. This decision will be communicated to Phil Trowbridge who will mobilize the crew members through telephone calls.

Natalie Landry, Matthew A. Wood, Rob Livingston, Andy Chapman, and possibly Gregg Comstock and Peg Foss, all of the NHDES Watershed Management Bureau, will be Field Sampling Team Leaders. During each sampling date, each of the Field Sampling Team Leaders will be in communication with the Project Manager via cellular phones in order to resolve any problems.

Great Bay Coast Watch

Ann Reid of Great Bay Coast Watch will organize volunteers to assist with the sampling effort.

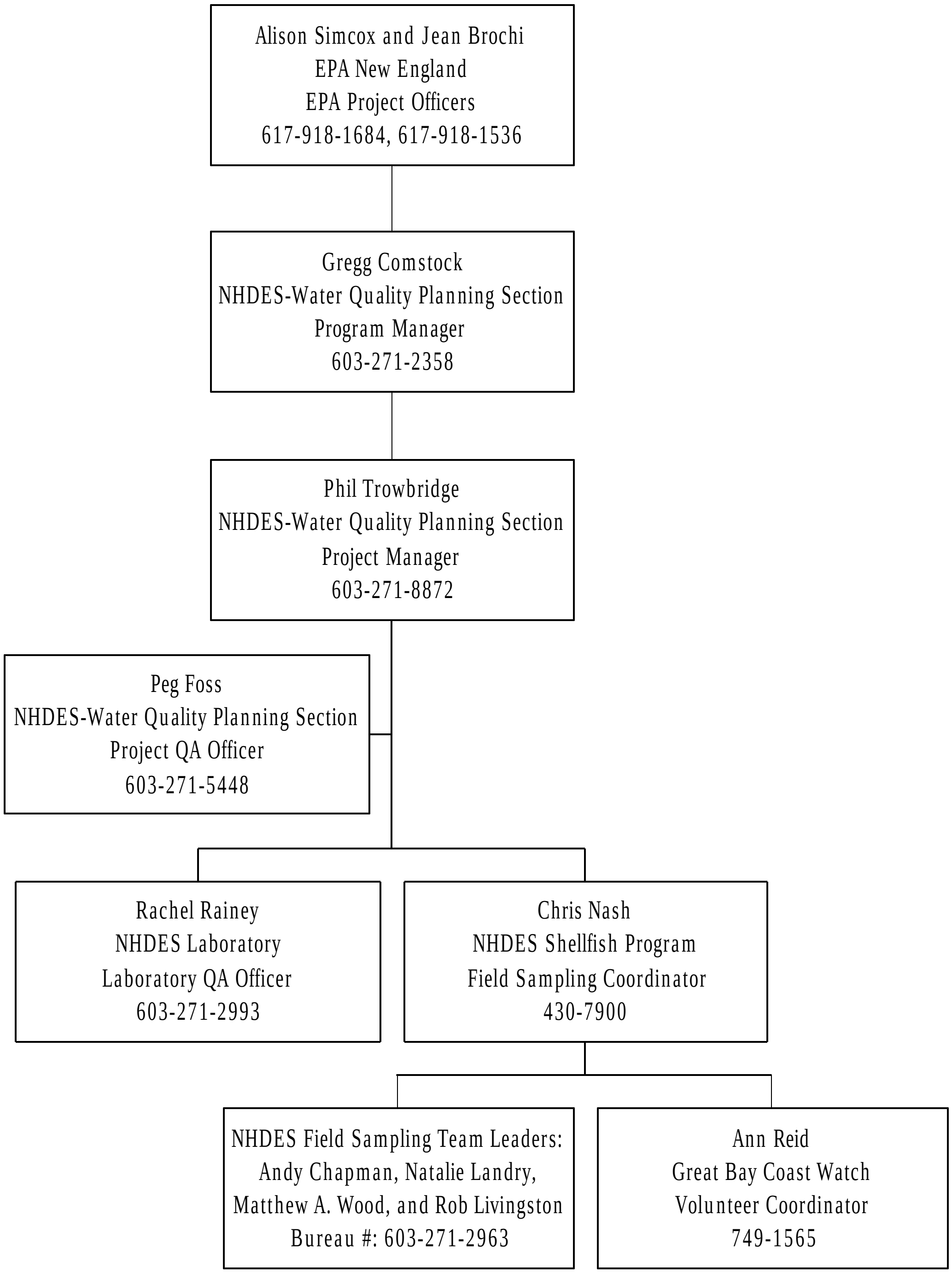
NHDES Laboratory

Rachel Rainey is the Project Manager and QA officer for the NH Department of Environmental Services Laboratory Services Unit (LSU). She will be responsible for conducting the analyses and communicating any analytical problems to the Project Manager.

The data generated by this study will be used by NHDES Water Quality Planning Section to complete a TMDL report to EPA Region I. These data will be made available to the public upon request.

Figure 1 shows an organizational chart for this project.

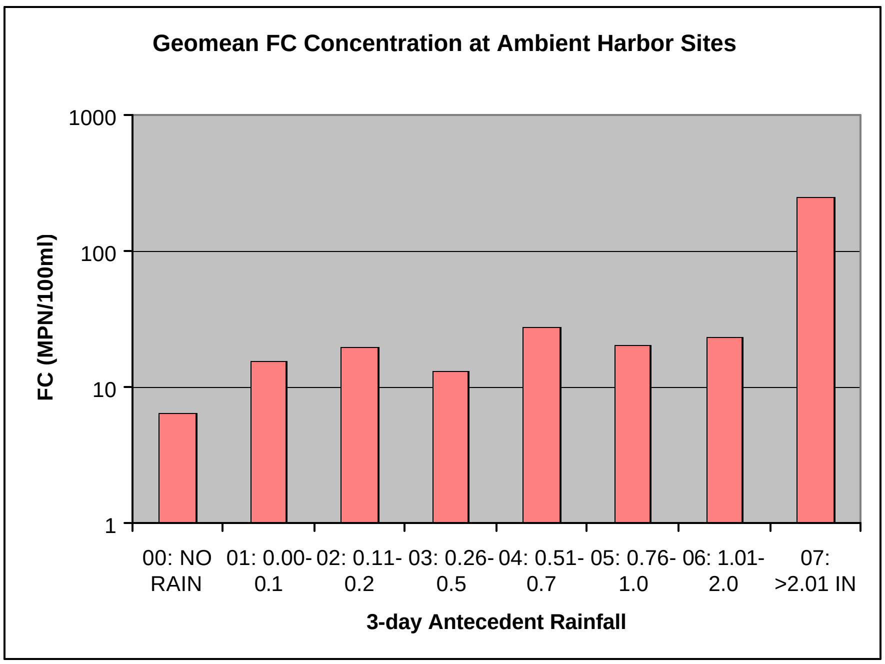
Figure 1. Project organizational chart



A5 – Problem Definition/Background

Hampton Harbor and its tributaries were included on NH's 1998 303(d) list of impaired waterbodies due to bacterial pollution (primarily during wet weather) that impairs its use for shellfishing (see Figure 2 below) (DES 1998). Over the past several years, NHDES and other agencies have focused on identifying pollution sources that contribute to wet weather contamination of Hampton Harbor. The goal of these efforts is to accurately identify and ultimately eliminate these sources (if possible), which contribute to the restrictions on shellfish harvesting that have been in place since 1994. The NHDES Shellfish Program has identified and sampled approximately 100 sources of stormwater to the estuary. The NHDES Watershed Assistance Section will soon have funding to address these types of sources. However, these funds can only be used for corrective actions in waterbodies for which a Total Maximum Daily Load (TMDL) has been developed.

Figure 2: Geometric mean concentrations of fecal coliforms at Hampton Harbor sites (1988-2001)



Note: The NSSP standard for geomean FC is 14 MPN/100ml.

NHDES has proposed the development of a bacterial TMDL for Hampton Harbor, targeted on wet weather sources of contamination. This study will provide information needed for the "Source Assessment" step of the TMDL; specifically, enhancing the existing data on stormwater sources through targeted monitoring and discharge estimation. Existing data on these sources consists of one sample per pipe from three different storm events, with no data on pipe discharge. To properly quantify bacterial loading from these sources, it is necessary to collect several samples from each source during the same storm, along with concurrent estimations of discharge. Simultaneous measurements of bacteria concentrations in the Harbor will provide information on the effects of bacterial loadings on the receiving waters. This detailed evaluation of loading and its effects will be used by NHDES in the TMDL study to: (1) provide for more accurate comparisons of the relative contributions of different bacteria sources (e.g., stormwater, WWTF discharges, natural background, boat discharges, etc.); (2) provide a more accurate linkage between water quality targets and sources; (3) enhance the source allocations developed, and (4) ultimately lead to a rigorous process for targeting restoration funds on the most significant sources of bacteria.

A6 – Project/Task Description

Training Tasks

- Field sampling staff will be trained by the Project Manager and the Field Sampling Coordinator on the sampling and analysis methods and safety measures that will be used for this program.

Sampling Tasks

- Stormwater samples will be collected from approximately 25 storm drain pipes or harbor tributaries. The samples will be analyzed for fecal coliform bacteria ("FC"). Three different storms of greater than 0.25 inches/day will be monitored. For each storm, samples of the stormwater will be collected approximately hourly in order to characterize changes in bacteria concentrations over the storm hydrograph.
- When stormwater samples are collected, the flow of stormwater from the pipe will also be measured in the field.
- Surface water samples from 10 ambient stations in the harbor will be collected simultaneously along with the stormwater samples. These data will be used to illustrate the effect of stormwater loadings on ambient water quality.

Analysis Tasks

- For each pipe, measurements of flow will be combined with bacteria concentrations to estimate the bacteria loading over the duration to the storm.
- FC concentrations at the harbor sites during the storm will be plotted against time to qualitatively evaluate the timing and magnitude of the response relative to the loading.

TMDL Preparation

- The results of the analyses as well as the raw data will be compiled in a TMDL report which is scheduled to be submitted to EPA Region I as a draft by the end of 2002. The public participation component of the TMDL and final revisions will be completed in 2003.

Table 2. Project Schedule Timeline

Activity	Dates (MM/DD/YYYY)		Product	Due Date
	Anticipated Date(s) of Initiation	Anticipated Date(s) of Completion		
QAPP Preparation	04/08/02	06/10/02	QAPP Document	06/10/02
Training	06/11/02	06/12/02	Training records	06/12/02
Wet-weather monitoring and analysis for 2 to 3 storms	06/13/02	10/31/02	Field and Lab Data Packages	10/31/02
TMDL Preparation	11/01/02	12/31/02	Draft TMDL Document	12/31/02
Public Participation	01/01/03	03/01/03	Public participation records	03/01/03
Final TMDL Report	03/01/03	05/01/03	Final TMDL Document	05/01/03

Based on EPA-NE Worksheet #10.

A7 – Quality Objectives and Criteria

Two environmental measurements will be made for this study: (1) FC concentrations in stormwater and ambient harbor water, and (2) flow of stormwater. Water temperature will also be measured but no regulatory decisions will be made based on this parameter. The data quality objectives for each of these measurements are described below.

Table 3: Accuracy and Precision Data Quality Objectives

Parameter	Measurement Range	Precision	Accuracy	Maximum Total Error (1)	Reporting Limit
Fecal Coliforms – Overall for stormwater samples (1ml dilution)	100-20,000 (#/100ml)	60% RPD	NA (see "accuracy" text)	±60%	100 (#/100ml)
Fecal Coliforms – Overall for ambient samples (10ml dilution)	10-2,000 (#/100ml)	40% RPD	NA (see "accuracy" text)	±40%	10 (#/100ml)
Stormwater flux	0-15 (cfs)	20% RPD	±32% (low flow, <0.5 cfs) ±14% (med flow, 0.5-3.0 cfs) ±8% (high flow, >3 cfs)	±38% ±24% ±22%	0.02 (cfs)
Water Temperature	-10 to 40 degC	NA	±0.5 degC	±0.5 degC	-10 degC

Notes:

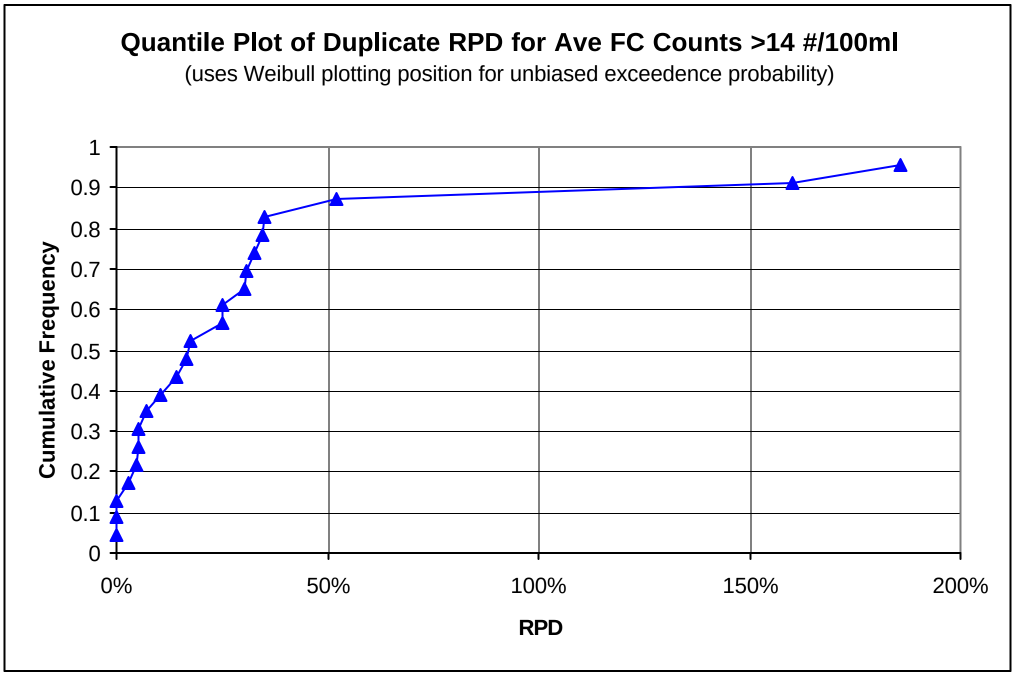
(1) Accuracy error and precision error can be assumed to be independent, random variables. Therefore, the total error in the measurement can be calculated to be root mean square of the two errors:

$$TotalError = \sqrt{AccuracyError^2 + PrecisionError^2}$$

<u>Precision</u>: The concentrations of FC in stormwater are expected to be highly heterogeneous due to fluctuating inputs from rainfall. The 1997 DES Stormwater Characterization Study (DES 1997) found RPDs for *E. coli* duplicate samples between 1.5 and 60% (25% on average) for two storm drains in Concord NH over seven storms. Differences between field duplicate samples collected from storm drains in Hampton Harbor will mostly represent heterogeneity in the stormwater medium, not lack of uniformity in the field sampling methods. As a result, the precision data quality objective for stormwater FC samples has been set at the highest RPD observed in the 1997 study (60%) to match the natural heterogeneity in stormwater that has already been observed.

For the FC samples from ambient harbor samples, the data quality objective for field duplicates will be 40% RPD. This value was determined after analyzing field duplicates of FC measurements (by plate counts) collected in Hampton Harbor by the DES Shellfish Program during 2000. For this study, FC concentrations in ambient samples are expected to be >14 #/100ml. Consequently, only the RPDs for samples with average FC concentrations > 14 #/100ml were used (n=21). A quantile plot of these data, show that greater than 80 percent of the samples were clustered together with RPDs less than 40% (see Figure 3). The few samples with RPDs greater than 40% plotted far away from the rest of the samples and appeared anomalous. Based on these data, an RPD of 40% appears to separate duplicate samples reflective of natural variability in the medium and duplicate samples reflective of potential sampling error. Therefore, 40% was adopted for the data quality objective for ambient harbor samples in this study.

Figure 3: Quantile Plot of RPD from Duplicate Ambient Samples for FC



The field duplicates of stormwater and ambient harbor samples will capture error from all stages of the data collection and analysis. Therefore, RPDs between field duplicates will be considered representative of the total error in the FC measurements.

Duplicate measurements of flow will be conducted to characterize heterogeneity in flow or field methods. The data quality objective for the field duplicates will be 20% RPD.

Accuracy: No accuracy objectives have been set for the FC analyses because there is no practical way to perform spiked samples or analyze standard reference materials for coliforms.

For flow measurements, the accuracy of the methods that will be used have been assessed by the DES Shellfish Program in Appendix A. The methods involve calculating the stormwater flux by measuring the velocity and cross sectional area of the flow. Flux estimates from these methods were checked against accurate measurements of flow (collecting the stormwater in container of known volume and recording the time). During the Hampton Harbor field work, it will not be possible to confirm the accuracy of this method because the bottom of the outfall pipes are set flush with the ground, and, therefore, cannot be evaluated using volumetric measurements. However, if the SOPs for flow measurements are followed (Appendix B), the resulting flow estimates should be accurate to within the limits established in Appendix A. These limits have also been adopted as the data quality objectives for stormwater flux.

Representativeness: The objective of this study is to make measurements that will be representative of the loading of bacteria from storm drains around Hampton Harbor. To that end:

- The storm drains that have been selected for the study were chosen because of their size, previous sampling data indicating elevated bacteria concentrations, and proximity to ambient harbor stations. As a result, these storm drains are expected to be representative of the major stormwater sources of bacteria to the harbor.

- To be representative of the stormwater loading, this study needs to capture the elevated FC concentrations during the "first flush" and to collect subsequent samples at a high enough frequency to characterize how quickly the first flush concentrations decline. By stationing the teams at key outfalls before the storm, this project will be sure to capture the important information of the first flush concentration. Subsequent measurements of bacteria and flow from the storm drains will be taken as frequently as possible, at approximately 30-60 minute intervals. Therefore, the proposed sampling design will capture in both the elevated FC concentrations of the first flush and the changing concentrations during the storm, so that the resulting loading estimate is representative of the overall loading from these pipes.
- The stations that will be sampled in the harbor are used by the Shellfish Program to assess growing areas and, therefore, are considered representative of the harbor. They are the stations that will be used to make future decisions about shellfish growing areas, which makes them uniquely representative of harbor conditions.

Comparability: The field and laboratory methods for this study are identical to those used by the DES Shellfish Program for shoreline surveys and other wet-weather monitoring projects. Therefore, the results will be comparable to other similar studies. The laboratory analyses by the Membrane Filtration Method are based on procedures from Standard Methods for the Examination of Water and Wastewater (18^{th} edition, 9222D).

Sensitivity. Background information on wet-weather FC concentrations in stormwater in Hampton Harbor exists, and the data show that the sensitivity of the proposed laboratory methods are adequate (expected FC concentrations >500 #/100ml in many pipes, see Tables 5 and 6 for data on individual stations). The quantification limit for stormwater flux in the table in Section A7 is based on field studies reported in Appendix A in which the method to be used for this study produced accurate measurements of flow down to 0.02 cfs at the Hubbard Road culvert on 4/1/02.

Completeness: This study proposes to monitor a total of three storms between June and October. However, the study will be sufficiently complete if two storms are monitored. Therefore, a data completeness percentage of 67% is needed.

Total Error For Project: The objective of this sampling program is to monitor loads of bacteria from individual storm drains over the course of three storms. The instantaneous loading from a storm drain at time i (L_i) (in bacteria/minute) will be calculated by (Peters et al., 1974):

$$L_i = CF \cdot F_i \cdot C_i$$

Where F_i is the stormwater flux from an individual drain at time i (in cfs) and C_i is the concentration of bacteria in the stormwater sample (in counts per 100ml) collected at the same time as the flux measurement. CF is a conversion factor of 16,992 (1000 ml/l*28.32 l/ft^3*60s/minute). The error associated with each instantaneous loading calculation will be the combination of the error in the measurements of F and C. The following equation defines the variance in L_i (Var(L)) given known variance in Fi and Ci (Var(F) and Var(C), respectively):

$$Var(L) = \left(\frac{\partial L}{\partial F}\right)^2 \cdot Var(F) + \left(\frac{\partial L}{\partial C}\right)^2 \cdot Var(C)$$

Assuming that the variance is approximately equal to the square of the absolute error (δL), the equation reduces to:

$$\frac{dL}{L} = \sqrt{\left(\frac{dF}{F}\right)^2 + \left(\frac{dC}{C}\right)^2}$$

Where

100% • $\delta L/L$ = the total percent error in instantaneous loading estimate;

100% • $\delta F/F$ = the total percent error in the stormwater flux estimate;

100% • $\delta C/C$ = the total percent error in the FC concentration.

Applying the maximum total error associated with the data quality objectives for FC in stormwater samples (60%) and stormwater flux measurements (22-38%) from Table 3, the maximum total error in each instantaneous loading estimate will be ±64-71%.

The cumulative loading of bacteria from each outfall over the course of the storm (for n stormwater samples) will be calculated by:

$$Ltot = \int_{t=0}^{t=t} L(t)dt \approx \sum_{i=1}^{i=n-1} \frac{(L_i + L_{i+1})}{2} \cdot (t_{i+1} - t_i) = \sum_{i=1}^{i=n-1} Lave_i \cdot \Delta t_i$$

Where Ltot has units of bacteria loaded over the course of the storm. The relative error for each (L_i +L_{i+1})/2 term ("Lave") in the summation will be approximately ($\delta L/L$)•√2. There will not be any significant error in the ($t_{i+1} - t_i$) term ("Δt") because this is simply the time between the collection of sample$_i$ and sample$_{i+1}$ (in minutes). Therefore, the total error for each product of $Lave_i$ and Δt_i will be ($\delta L/L$)•√2. Assuming that each $Lave_i$•Δt_i term in the summation is approximately equal to their average values (Lave and Δt, respectively), Ltot for n stormwater samples can be approximated by:

$$Ltot = \sum_{i=1}^{i=n-1} Lave_i \cdot \Delta t_i \approx (n-1) \cdot Lave \cdot \Delta t$$

and the cumulative error for Ltot can be expressed as:

$$Var(Ltot) \approx (n-1)^2 \cdot Var(Lave \cdot \Delta t)$$

Assuming that the variance of Ltot is approximately equal to the square of the absolute error, δLtot, this expression can be rewritten as:

$$\frac{dLtot}{Ltot} = \frac{d\,(Lave \cdot \Delta t)}{Ltot} \cdot (n-1)$$

Substituting (n-1) • Lave•Δt for Ltot on the right hand side and then ($\delta L/L$)•√2 for δ(Lave•Δt)/Lave•Δt shows that the relative error in the cumulative loading estimate will be equal to the average relative error in the individual loading estimates:

$$\frac{dLtot}{Ltot} = \frac{d\,(Lave \cdot \Delta t)}{Lave \cdot \Delta t} = \left(\frac{dL}{L}\right) \cdot \sqrt{2}$$

Therefore, for the data quality objectives listed in Table 3, the maximum error in the cumulative loading estimate will be ±64-71%. The majority of this error is associated with the high data quality objective for precision for FC in stormwater samples (60% RPD). This high precision value is due to real heterogeneity in FC concentrations in the stormwater samples, and therefore cannot be eliminated.

A8 – Special Training/Certification

Prior to the first storm sampling event, all the Field Sampling Team Leaders for this project will be trained in the methods for collecting stormwater samples and measuring flows (as well as field data sheets for recording measurements and sample numbers). The Field Sampling Team Leaders will be taken to the field sampling locations to orient them to the area. Chris Nash and Andy Chapman of the DES Shellfish Program will conduct the training because Shellfish Program methods will be used for this study. Phil Trowbridge, the Project Manager, will brief the Team Leaders on logistics for each sampling effort including: where/when samples should be delivered, emergency communication networks, and personal protective equipment. Attendance will be mandatory for all Field Sampling Team Leaders. Attendance sheets will be kept on file in the DES Water Quality Planning Section office.

Table 4: Special Personnel Training Requirements

Project function	Description of Training	Training Provided by	Training Provided to	Location of Training Records
Storm drain monitoring	Field methods for collecting FC samples and measuring flows and field sampling logistics. This training will be conducted once at the beginning of the field season.	Chris Nash Phil Trowbridge	All Field Sampling Team Leaders	DES Water Quality Planning Section TMDL records

Based on EPA-NE Worksheet #7.

A9 – Documents and Records

QA Project Plan: The Project Manager will be responsible for maintaining the approved QA Project Plan and for distributing the latest version of the plan to all parties on the distribution list in section A3. A copy of the approved plan will be on file at the DES Water Quality Planning Section offices in Concord.

Field Data Reports: The field data sheets will be used for this project. The Project Manager will collect all field data sheets by the end of each sampling day. All the field data sheets will be photocopied and then distributed in the following manner:

- NHDES Shellfish Program Routine Monitoring QA/Field Data Sheet (Appendix C): Field observations for ambient harbor samples will be recorded on this sheet during the ambient harbor runs. Pertinent information will be transferred to the DES Laboratory's Login and Custody Sheet (see below). The original field data sheets for the ambient sites will be given to the DES Shellfish Program for data entry. The photocopies will remain with the Project Manager.
- DES Laboratory's Login and Custody Sheets (Appendix D): Field data on sample collection at pipes and tributaries will be recorded directly on this form. Field data for the ambient harbor samples will be transferred to this form from the DES Shellfish form after each round of interval sampling. The water temperature will be recorded in the "other" column. The original login and custody sheet will be delivered to the DES Laboratory along with the samples. The photocopies will remain with the Project Manager.
- NHDES Stormwater Flux Field Data Sheet (Appendix E): Field data on measured stormwater fluxes will be recorded in the field on the standardized form. The Project Manager will retain the

original field data sheets for stormwater fluxes and will give the copies to the DES Shellfish Program for redundancy.

Laboratory Data Reports: Data packages from the laboratory will be hardcopy laboratory data sheets containing the FC concentration for each sample.

Final Report to EPA: Field and laboratory data will be reported to EPA Region I in a TMDL report for Hampton Harbor. Phil Trowbridge will prepare the report. A draft of the report is expected to be complete by 12/31/02 (depending on the number of suitable storms that occur in 2002).

Archiving: The original field and laboratory data sheets, QA Project Plan, and the final report to EPA will be kept on file by the DES Water Quality Planning Section for a minimum of 10 years after the publication date of the final report.

B1 – Sampling Process Design

There are two components to the sampling design for this project: (1) stormwater sampling at approximately 25 storm drains and tributaries around Hampton Harbor; and (2) wet-weather monitoring at 10 stations inside the harbor.

Sampling Locations

Approximately 100 stormwater sources have been identified around the harbor. A set of approximately 25 stormwater pipes and tributaries have been selected for intensive wet-weather field sampling. These pipes were selected by the DES Shellfish Program, DES Water Quality Planning Section, and DES Watershed Assistance Program based on the following criteria:

- **Geographic proximity to the actual growing waters of the harbor.** All the pipes with diameters of 12 inches or greater within 5,000 feet of shellfish area monitoring stations were selected to define the universe of pipes close to the growing areas (see Figures 4 or 5 for the boundary of the 5,000 ft buffer). Of these 20 pipes, four (HHPS040, HHPS041, HHPS043, HHPS044) were eliminated because they only received road runoff from a bridge (an approximately 200 ft x 30 ft area). One other pipe (HHPS065) was eliminated because low bacteria concentrations have been consistently recorded in past stormwater samples. One pipe with a 10 inch diameter (HHPS062) was added to the list because it is co-located with another pipe on the list (HHPS061). Therefore, a total of 16 pipes will be monitored for this study. Influences of sources farther upstream from the growing areas will be assessed by monitoring key tributaries at the point where they discharge to the Harbor. A total of 9 tributary stations will be monitored. The combined number of storm drain and tributary stations will be 25.
- **Demonstrated high FC concentrations from past sampling.** The pipes chosen to be monitored comprise the pipes with 8 of the 10 highest FC concentrations measured during wet weather on 9/13/00.
- **Likely to have high flows, based on pipe diameter or nearby land use.** The pipes chosen for the study are located within the developed areas of Hampton and Seabrook. This area has the greatest concentration of impervious surfaces and development within the watershed of Hampton Harbor.
- **Located in areas that may have sources of bacteria related to development.** The pipes that will be monitored are in the most developed areas of Hampton and Seabrook where human sources of bacteria are possible. Monitoring at tributary stations will be used to assess bacteria sources upstream in the watershed.

Based on these criteria, the selected monitoring stations for storm drain pipes and tributaries are as follows (see Figure 4 for locations):

Table 5: Stormwater pipes and tributaries for this study

Field Team	Pipe Station No.	Pipe Diameter (in)	Wet-weather FC range (1,2) (#/100ml)	Dry-weather FC range (1,2) (#/100ml)	Comments
Pipe Team 1	HHPS061	20	660-7,200	20-30	Next to 062
Pipe Team 1	HHPS062	10	60-2,900	20-21	Next to 061
Pipe Team 1	HHPS073	12	8000	No data	
Pipe Team 1	HHPS072	18	500-5480	No data	Next to 071
Pipe Team 1	HHPS071	28	120-10,560	20	Next to 072
Pipe Team 1	HHPS070	28	7,060-12,840	20-660	
Pipe Team 2	HHPS063	15	500-3,420	10-20	No flow meas.
Pipe Team 2	HHPS054	12	10,220	No data	(3) No flow meas.
Pipe Team 2	HHPS055	18	5,960	20	(3)
Pipe Team 2	HHPS056	36	220-10,320	1-3	(3) No flow meas.
Pipe Team 2	HHPS057	18	20-1,760	1-2	(3) No flow meas.
Pipe Team 2	Conveyances from wetland areas NE of Rte 101 (HHPS015)	42	1,845-3,280	120-258	Next to 016 (a.k.a. HHT7)
Pipe Team 2	Same as above (HHPS016)	60	4,300-7,740	475-880	Next to 015 (a.k.a HHT6)
Pipe Team 2	Tide Mill Creek (HHT8)	NA-Tributary	0.5-138	1-40	Downstream of WWTF
Pipe Team 3	HHPS066	36	200-13,400	40-980	(4) 30 minute data
Pipe Team 3	HHPS067	12	100-8,000	14-20	(4) 30 minute data
Pipe Team 3	HHPS068	36	700-15,600	20-31	(4) 30 minute data
Pipe Team 3	HHPS069	36	740-20,800	17-20	(4) 30 minute data
Trib Team	HHPS182	30	70-7,300	90-2,200	(5) No flow meas.
Trib Team	Blackwater River (HHT1)	NA-Tributary	0.7-64	0.5-10	
Trib Team	Mill Creek (HHT2)	NA-Tributary	7-760	18-190	
Trib Team	Hampton Falls River (HHT4)	NA-Tributary	8-450	1-15	
Trib Team	Taylor River (HHT5)	NA-Tributary	1-370	17-51	
Boat Team	Browns River (HH35)	NA-Tributary	No data	No data	
Boat Team	Hampton River (HH15)	NA-Tributary	No recent data	No recent data	Head of the Hampton River

Notes:

(1) Wet-weather data defined as either stormwater data collected during a rainstorm or data from tributary stations where more than 0.5 inches of rain had fallen in the previous 3 days (DPHS, 1994). Dry weather samples were samples collected when the three day antecedent rainfall was zero.

(2) All FC data on this table are concentrations measured as counts in #/100ml.

(3) HHPS054, HHPS055, HHPS056, and HHPS057 are in the same general area. Of these four, the greatest area is drained by HHPS055. The flow from HHPS055 passes under a roadway to become HHPS056. The only additional contribution of stormwater between HHPS055 and HHPS056 is HHPS054 and some road run-off. HHPS054 only receives flow from a small catchbasin nearby and bacteria from HHPS054 will be captured by the sample taken at HHPS056. HHPS057 is a broken culvert on which flows cannot be measured. Therefore, for this set of drains, bacteria samples will be collected from all four pipes; however, stormwater flow will only be measured at HHPS055. If roadwork on Highland Avenue is complete, the flow measurement at HHPS055 can be taken in a grated culvert a short distance upstream. It will be assumed that the flow from HHPS054 is approximately equal to the flow from HHPS056. The flow from HHPS054 and HHPS057 cannot be estimated reliably but bacteria measurements throughout the hydrograph will provide useful information about bacteria loads from this culvert.

(4) HHPS066, 067, 068, and 069 drain approximately one half of the developed portion of Hampton Beach. These four pipes have outfalls at the same location. Due to the size of their collective drainage area and their proximity to each other, one team will remain at these pipes during the storm and will collect samples and conduct flow measurements at approximately 30 minute intervals.

(5) HHPS182 has two large culverts that are sealed with “duckbill” tide gates. The duckbills prevent measurements of flow in the culverts. However, the northern pipe receives most of its flow from two pump stations so total flow during a storm can be estimated from pump station records kept by the Seabrook Department of Public Works. The flow from the southern pipe will be estimated using flow from the northern pipe and the ratio of the area drained by the southern pipe to the area drained by the northern pipe. Stormwater samples will be collected from the pool of water where these two pipes discharge to characterize the fluctuations in bacteria concentrations throughout the hydrograph.

Simultaneous with the storm drain sampling, the 10 ambient stations in the harbor will be sampled for FC. These stations cover the full extent of the harbor and its major tributaries and are considered representative of the major shellfish growing areas in Hampton Harbor (Figure 5). Data from the ambient harbor stations during the storm will be used to evaluate the effects of stormwater bacteria loads on ambient water quality in the growing areas.

Table 6: Ambient harbor stations for this study

Field Team	Station No.	Wet-weather FC geomean and range (1,2) (MPN/100ml)	Dry-weather FC geomean and range (1,2) (MPN/100ml)	Comments
Boat Team	HH1A	**24.3** (1.8-790)	**7.8** (1.8-130)	
Boat Team	HH10	**20.8** (1.8-1,300)	**5.6** (1.8-149)	
Boat Team	HH11	**16.8** (1.8-1,300)	**6.8** (1.8-149)	
Boat Team	HH5B	**25.4** (2-1,300)	**6.5** (1-79)	
Boat Team	HH5C	**29.0** (1.8-1,600)	**6.5** (1.8-79)	
Boat Team	HH12	**18.6** (1.8-1,300)	**6.3** (1.8-140)	
Boat Team	HH17	**23.3** (1.8-490)	**7.9** (1.8-240)	
Boat Team	HH18	**15.6** (1.8-330)	**4.4** (1.8-95)	
Boat Team	HH19	**25.9** (1.8-1,300)	**7.4** (1.8-130)	
Boat Team	HH2B	**26.8** (1.8-1,300)	**6.8** (1.8-230)	

Notes:

(1) Wet weather sample are defined as samples collected when there had been more than 0.5 inches of rain over the previous 3 days (DPHS, 1994). Dry weather samples are defined as samples for which the three day antecedent rainfall was zero.

(2) All FC measurements on this table are MPN in MPN/100ml. Data summarized are all results from 1988 through 2000 for low-tide samples (excluding split samples and emergency closure sampling). The geometric mean concentration for all the samples is shown in **bold**. The range is shown in parentheses.

Selection of Storms for Wet-Weather Monitoring

Sampling will be initiated for storms that are predicted to have total rainfall >0.25 inches per 24 hours. Sampling will begin in the spring of 2002 and will conclude by late fall 2002. Up to 3 storms will be monitored. Based on an assessment of precipitation data from the nearby station in Durham NH (see table below), 15 to 29 storms of at least 0.25 inches daily precipitation are expected between June and October. For this study, storms that begin a few hours prior to the time of low tide will be preferred because many of the storm drains are submerged at high tide. Storms will also have to occur during daylight hours, and the normal workweek (excluding Fridays). Short-term storms, such as thunderstorms, will not be targeted because it would be difficult to mobilize field teams on such short notice. Given these restrictions, only a fraction of the storms of >0.25 inches will be suitable for this study. The expected number of storms meeting all the criteria is 2 or 3 based on the following assumptions and equation:

- Assume that storms occur randomly relative to tide, daylight hours, and days of the week;
- Assume that tide, daylight hours, and days of the week are independent;
- Assume that that the probability of a storm occurring at low tide is 0.5;
- Assume that the probability of the storm occurring during daylight hours is 0.5;
- Assume that the probability of the storm occurring between Monday and Thursday is 0.6,
- Then the expected number of storms will be the total storms greater than 0.25 inches (15 to 29) multiplied by 0.5*0.5*0.6, which equals 2 or 3 integral storms.

Table 7: Number of storms of different size classes recorded in June-October in Durham

PRECIP (inches)	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
0-0.1	122	112	121	118	119	124	125	122	120	132
0.11-0.25	10	12	8	10	14	11	8	10	14	6
0.26-0.50	8	12	12	13	5	11	13	10	7	8
0.51-0.75	2	7	3	4	6	2	2	3	3	3
0.76-1.00	2	6	3	4	5	3	2	3	1	1
1.01-2.00	8	4	5	2	3	2	2	5	4	3
2.01+	1		1	2	1		1		3	
>0.25	21	29	24	25	20	18	20	21	18	15

If no suitable storms have occurred by September 1, 2002, it may be necessary to target smaller storms. The decision to target smaller storms will be made by the Project Manager after consulting with the rest of the project team and the EPA TMDL Project Officer. Sampling will be done for up to three storms.

Sampling Schedule

When an appropriate storm is predicted, five sampling teams will be dispatched to Hampton Harbor: 3 "pipe teams" for stormwater sampling in pipes, 1 "trib team" for collecting samples from tributary sites, and 1 "boat team" to collect ambient harbor samples. Each team will collect "pre-storm" samples, "first flush" samples, and then samples at 30-60 minute intervals for the first 2-3 hours of the storm. Each team will be lead by a Field Team Leader from NHDES and a volunteer from Great Bay Coast Watch.

Table 8: Field sampling team members

Team	Leader	Members
Pipe Team 1	Matthew A. Wood or Rob Livingston	1 Great Bay Coast Watch volunteer
Pipe Team 2	Andy Chapman	1 Great Bay Coast Watch volunteer
Pipe Team 3	Phil Trowbridge	2 Great Bay Coast Watch volunteers
Trib Team	Natalie Landry	1 Great Bay Coast Watch volunteer
Boat Team	Chris Nash	1 Great Bay Coast Watch volunteer

* Alternates: Peg Foss (QA Project Officer), Gregg Comstock (Program Manager)

Pre-Storm Samples

Each team will be sent to its starting location to collect "pre-storm" water samples before precipitation begins. The pipe teams will also measure "pre-storm" flows. It will not be possible to collect pre-storm samples at all of the pipes because the teams must remain in place in order to capture the first flush samples. However, the following starting locations have been chosen to represent the major stormwater outfalls.

Table 9: Field team locations for "pre-storm" samples

Team	Location for "Pre-Storm" Samples
Pipe Team 1	HHPS071, HHPS072. These two outfalls are collocated so it will be possible for the team to collect samples from multiple pipes at the same time.
Pipe Team 2	HHPS054, HHPS055, HHPS056, HHPS057. These four outfalls are collocated.
Pipe Team 3	HHPS066, HHPS067, HHPS068, HHPS069. These four outfalls are collocated.
Trib Team	This team will attempt to collect a full suite of samples from all their sites before the rainfall begins (approximately 1 hour required).
Boat Team	This team will attempt to collect a full suite of samples from all their sites before the rainfall begins (approximately 1 hour required).

First Flush Samples

The pipe teams will remain at their starting locations until they notice a significant increase in stormwater flow from the pipe at which point they will collect a "first flush sample". The Trib and Boat teams will collect another round of samples from all of their stations over the first hour of the storm. As explained in the previous section, it will not be possible to collect first flush samples at all of the pipes due to the limited number of field teams. The locations chosen for first flush samples are the major outfalls that drain the majority of stormwater from Hampton. Because each pipe will have a different response time to the rainfall, the first flush samples at all of the pipes will not be taken at the same time – but rather at the time each individual pipe demonstrates a response to the rainfall.

Table 10: Field team locations for "first-flush" samples

Team	Location for "First Flush" Samples
Pipe Team 1	HHPS071, HHPS072. These two outfalls are collocated so it will be possible for the team to collect samples from multiple pipes at the same time.
Pipe Team 2	HHPS054, HHPS055, HHPS056, HHPS057. These four outfalls are collocated.
Pipe Team 3	HHPS066, HHPS067, HHPS068, HHPS069. These four outfalls are collocated.
Trib Team	This team will attempt to collect a full suite of samples from all their sites during the first hour of the storm (approximately 1 hour required).
Boat Team	This team will attempt to collect a full suite of samples from all their sites during the first hour of the storm (approximately 1 hour required).

Interval Samples

After collecting the first flush samples, the pipe teams will move to their next location as specified on the following table. For the last sample of each interval, they will return to the site where the collected the first flush sample. The Trib and Boat teams will continue to rotate through all of their stations. Each team will rotate through all of their sites every 30 to 60 minutes during the first 2-3 hours of the storm. The stations where flow will not be measured (as discussed in Section B1) are marked. The field teams will continue to collect samples until either (1) the Project Manager terminates the effort; or (2) the stormwater outfalls assigned to the team are inundated by the rising tide.

Table 11: Field team locations for "interval" samples

Team	Locations for Interval Samples	Frequency	Duration
Pipe Team 1	1. HHPS061 & HHPS062 2. HHPS070 3. HHPS073 4. HHPS071 & HHPS072	Approximately hourly	2-3 hours (2-3 complete sets of samples)
Pipe Team 2	1. HHPS063 [no flow] 2. HHPS016 & HHPS015 3. HHT8 [no flow] 4. HHPS054/055/056/057 [flow only at HHPS055]	Approximately hourly	2-3 hours (2-3 complete sets of samples)
Pipe Team 3	1. HHPS066, HHPS067, HHPS068, HHPS069.	Approximately every 30 minutes	2-3 hours (4-6 complete sets of samples)
Trib Team	1. HHT1 [no flow] 2. HHT2 [no flow] 3. HHT4 [no flow] 4. HHT5 [no flow] 5. HHPS182 [no flow]	Approximately hourly	2-3 hours (2-3 complete sets of samples)
Boat Team	10 harbor sites plus HH35 and HH15	Approximately hourly	2-3 hours (2-3 complete sets of samples)

[no flow] = a flow measurement will not be made at this location.

Field Documentation

When the field samplers collect bacterial samples at a stormwater pipes and tributary stations, they will also note time, and water temperature (in the "other" column) on the Laboratory Login and Custody Sheet (Appendix D). Flow measurements will be recorded on the Stormwater Flux Field Data Sheet (Appendix E)

At harbor stations, the field samplers note time and water temperature on the NHDES Shellfish Program Routine Monitoring QA/Field Data Sheet (Appendix C). Pertinent information will be transferred from this sheet to the Laboratory Login and Custody Sheet (Appendix D) after each sampling interval.

Summary

The total number of stormwater samples that will be collected for this project range from 132 to 171 samples per storm. The number of QC samples will be discussed in section B5.

B2 – Sampling Methods

Fecal Coliforms

Samples are collected in 250 mL-clear, polyethylene, pre-sterilized Nalgene bottles, supplied by the DES laboratories. On sample bottle labels, the sample date, sample time, and sample site identification code will be recorded using water proof/ indelible ink.

The bacterial sample will be collected by positioning the mouth of the bottle opposite the direction of flow. If the water is deep enough, the sample should be collected using a sampling pole by thrusting the bottle 8-12 inches under the surface of the water using a continuous "U" shaped motion until almost full, leaving a one-inch air space. Samples are collected with the container completely submerged, so as to minimize the collection of water on the immediate surface. The bottle may need to be shaken to remove water, allowing for a one-inch air space. Samples are collected without disturbing the substrate. If the substrate is disturbed while collecting a sample, the sampler will discard the sample and bottle and will collect another sample away from the disturbed area to minimize contamination possibilities.

Samples will be immediately stored on ice or ice pack in a light-tight cooler until delivery to the laboratory.

The temperature of all samples are measured using an infrared sensor and recorded when they are delivered to the laboratory to confirm that the proper temperature was maintained, preferably between 0-10°C, during sample collection and transport.

Stormwater Flux

Stormwater flux will be measured at each stormwater pipe by measuring the cross sectional area of flow in the pipe and its average velocity. For flows greater than 2 inches in depth and greater than 0.1 ft/s (the detection limit of the meter), current meters from Global Water will be used to measure the velocity. For shallower flows or flows less than 0.1 ft/s, the velocity will be inferred from the time required for a miniature float to move a known distance. The protocols for making the flow measurements are attached in Appendix B. An evaluation of the accuracy of the methods is attached in Appendix A.

Temperature

Water temperature at each sample site is measured using a Reotemp, stainless steel, bi-metal thermometer or equivalent. Water temperature is measured by placing the thermometer in the water until the thermometer reading has stabilized. If this method is not appropriate for the field conditions, a sample will be collected in a sample bottle, the thermometer will be inserted into the bottle to measure the temperature, and the water will be discarded after the temperature has been recorded. The temperature is measured by looking squarely at the face of the thermometer. The water temperature for each stormwater and tributary sample will be recorded in the "comments" field of the DES Laboratory Login and Custody Sheet (Appendix D). The water temperature for each ambient water sample will be recorded on the second page of the DES Shellfish Program Routine Monitoring QA/Field Data Sheet (Appendix C)

Table 12: Sample Requirements

Analytical parameter	Collection method	Sampling SOP	Sample volume	Container size and type	Preservation requirements	Max. holding time (preparation and analysis)
Fecal coliforms	Grab	See text	150 mL	250 mL sterile clear polyethylene	Chilled to = 10ºC	8 hours (except under extenuating circumstances - see B3)
Water Temperature	measured in-situ	See text	NA	NA	NA	NA
Stormwater flux	measured in-situ	See text	NA	NA	NA	NA

Based on EPA-NE Worksheet #12b.

<u>Field Corrective Measures</u>

The Project Manager will be responsible for making decisions in the field to correct for any field sampling problems. All of the Field Sampling Team Leaders and the Project Manager will have mobile phones for communication in the field. If a Field Sampling Team Leader is not able to follow the SOPs for sampling listed in the QA Project Plan, they will call the Project Manager and explain the problem. The Project Manager will decide on the course of action and will relay consistent information to all the other Field Sampling Team Leaders.

B3 – Sample Handling and Custody

Water samples for bacteria analysis will be stored and transported on ice in coolers. The water temperature of the samples is measured by DES Laboratory staff using an infrared sensor and is recorded on the data sheet at the time of sample delivery. The samples will be delivered to and analyzed by the laboratory within 8 hours of collection. Although DES will make every effort to meet the 8 hour holding time requirement, if the stormwater sampling must occur after 5 pm due to timing of the storm and low tide, the samples will not be analyzed until the following morning. The samples would be stored on ice in the secure DES Laboratory cold room overnight and would be analyzed no later than 30 hours after collection. While this duration exceeds the holding time for the Membrane Filtration Method (SOP 10.34a), 30 hours is considered an acceptable holding time by APHA (1970). If samples are stored in the laboratory cold room, they will be signed in and signed out of storage on the laboratory login and custudy sheet with the date, time, and staff noted.

Each sampling team will be responsible for delivering their samples and field data sheets to the Project Manager at two times during the sampling day.

1. Between the first and second set of interval samples, the field teams will drop off all their samples collected up to that point and their associated Laboratory Login and Custody Sheets (Appendix D) with the Project Manager at the parking lot behind the Hampton Police Department (corner of Brown and Ashworth Streets). The Project Manager will transfer the samples iced coolers and confirm that all samples are properly documented with field sheets. Then, these samples will be delivered by a Great Bay Coast Watch volunteer in one batch to the DES Laboratory. The volunteer will make copies of the Login and Custody Sheets and will leave them with the Laboratory staff to deliver to the Project Manager.
2. The sampling teams will reconvene again at the end of the sampling day at this same location. All other samples and all field data sheets will be transferred to the Project Manager. The Project

Manager will confirm that all samples are properly documented with field sheets before releasing the field teams. The Project Manager will deliver the second batch of samples to the laboratory and will make copies of all field data sheets. The copies of the field data sheets will be distributed according to the plan in Section A9.

B4–Analytical Methods

Fecal coliforms in stormwater and ambient samples will be analyzed by the DES Laboratory using the Membrane Filtration Method (SOP 10.43a on file with EPA). This will be conducted by the DES Laboratory. Samples of stormwater will be analyzed at the 1 ml dilution. Pre-storm samples and samples from the ambient harbor sites will be analyzed at the 10 ml dilution.

The Laboratory QA Officer will be responsible to resolving any problems with the laboratory method and informing the Project Manager of the quality of the data.

B5 – Quality Control

Precision Calculations

Precision of FC and flow measurements will be assessed from field and laboratory duplicates using relative percent difference (RPD):

$$RPD = \frac{|x_1 - x_2|}{\frac{x_1 + x_2}{2}} \times 100\%$$

where x_1 is the original sample concentration (or flow)
x_2 is the duplicate sample concentration (or flow)

Fecal Coliforms

Overall Precision: Each team will collect a field duplicate for every 10^{th} fecal coliform sample. The RPD between the duplicate pair will be calculated using the formula at the beginning of section B5. If one of the two samples is qualified as "less than" or "greater than" a value, the reported value will be used in the RPD calculation. The RPD will be compared to the data quality objective. If the RPD is less than or equal to the data quality objective, the duplicate samples will be considered "in control". If the RPD is greater than the data quality objective, the two duplicate samples will be flagged for investigation by the Project QA Officer.

Stormwater Flux

Each team will repeat every 10th field measurement of stormwater flux. The RPD between the duplicate pair will be calculated using the formula at the beginning of section B5. If the RPD is less than or equal to the data quality objective, the duplicate samples will be considered "in control". If the RPD is greater than the data quality objectives, the two duplicate samples will be flagged for investigation by the Project QA Officer.

Project QA Officer Investigations

For any measurement flagged for investigation, the Project QA Officer will review the field and laboratory data sheets and talk with the field sampling team that collected the sample to determine if the large variation can be explained by deviation from field sampling SOPs. If all SOPs were appropriately followed, the difference between the duplicate samples will be considered representative of natural heterogeneity in the sampled medium. The conclusions of the Project QA officer will be documented in a report to the Project Manager.

B6/B7 – Instrument/Equipment Testing, Inspection, Maintenance, Calibration and Frequency

Field instruments used during water sample collection include a Global Water "Global Flow Probe" flow meter and a Reotemp thermometer.

Global water flow meters are calibrated at least annually when their batteries are changed. See Appendix B for calibration procedures.

The Reotemp thermometer is calibrated annually at a minimum. The date of calibration is recorded on a piece of tape attached to the thermometer. Temperature measurements will not be used to make any management decisions. This information will be collected to provide background information.

Laboratory instruments and equipment are inspected, maintained and calibrated by the laboratory. Refer to the NHDES Standard Operating Procedures for the Fecal Coliform Test by Membrane Filtration (SOP 10.43a) and the Quality Systems Manual: State of New Hampshire Department of Environmental Services Laboratory Services Unit.

Table 13: Instrument/Equipment Calibration Table

Equipment name	Procedure	Frequency of calibration	Acceptance criteria	Corrective action	Person responsible
Global Water "Global Flow Probe"	Appendix B	Annually	Code = 33.31	Reset code to 33.31	Field operator

Based on EPA-NE Worksheet #14.

B8 – Inspection/Acceptance Requirements for Supplies and Consumables

Field Inspection: Sample bottles will be inspected by field personnel before sample collection. Bottles that may have been contaminated will be returned to the laboratory for sterilization.

Laboratory Inspection: The procedures used by the DES Laboratory to inspect supplies and consumables are described in SOP 10.43a.

B9 – Non-direct Measurements

Tidal data are used in making decisions on when to sample. Samples are collected during tidal conditions suitable for sample collection. Data on time of low tide are acquired from National Oceanic and Atmospheric Administration tide charts, using times for the Portland, ME base station (available at http://www.co-ops.nos.noaa.gov/cgi-bin/predictions.cgi?stn=8418150+Portland+,+ME). Using this information and the tidal lag for each sampling site, the appropriate tidal conditions for sampling can be determined.

Rainfall data are used to measure the amount of liquid precipitation from each storm. The weather station from which data will be acquired is Seabrook (North Atlantic Energy Service Corporation), NH.

Predictions of weather from internet sources and the National Weather Service will be used to identify potential storms meeting the criteria for this study. Some specific sources include: www.accuweather.com and the National Weather Service office in Grey ME (207-688-3216 or 800-482-0913 after 5 pm).

Pump station records from the Town of Seabrook DPW will be used to estimate total discharge through the northern outfall at HHPS182. The pumps are rated at 2,340 gallons/minute. DPW staff will read the log of pump run time before the target storm and again at the end of the DES sampling round. The total amount of time that the pumps ran during this time will be multiplied by the pumping rate to estimate the total amount of water discharged during the time that water samples were collected from the outfall.

B10 – Data Management

Data Recording Procedures: Field data will be recorded on standardized field data sheets (Appendices C, D, and E). When completing these forms, the field staff will follow the procedures from the DES *Quality Management Plan (QMP)* (June 2001) sections 6.3 and 8.7, especially the sections excerpted below:

- 6.3.a. The records shall clearly indicate the date of the field observation, sample collection, sample preparation, equipment calibration or testing, and other related activities.
- 6.3.b. The records shall include the identity of personnel involved in making observations, collecting field data, sampling, preparation, calibration, or testing.
- 6.3.c. The record-keeping system shall facilitate the retrieval of all working files and archived records for inspection and verification purposes.
- 6.3.d. All documentation entries shall be signed or initialed by responsible staff. The reason for the signature or initials shall be clearly indicated in the records such as “sampled by”, “prepared by”, or “reviewed by”.
- 6.3.e. All generated data except those that are generated by automated data collection systems, shall be recorded directly, promptly, and legibly in permanent ink.
- 6.3.f. Entries in records shall not be obliterated by methods such as erasure, overwritten files, or markings. All corrections to record-keeping errors shall be made by one line marked through the error and initialed. These criteria also shall apply to electronically maintained records, where applicable.

For the purposes of this study, the identities of all field staff should be recorded as their first initial and full last name. Also, because the sampling will occur during rainstorms, waterproof paper and pencils will be used to record the field data.

Manipulations of Raw Data: There will be no manipulations of raw data prior to data entry.

Data Entry Procedures: In accordance with Section 9.2 of the QMP, stormwater data from field and laboratory data sheets will be entered into a database by one DES staff person and then checked by another. The person who entered the data and the person who checked the data entry will both sign the data sheet. The Project Manager will also sign the data sheet after the data entry check has been performed. Any discrepancies between the data sheets and the database will be resolved by the Project Manager.

Ambient harbor data will be entered following the protocols of the DES Shellfish Program. Chris Nash is responsible for data entry. All ambient data are managed in Microsoft Access databases. As data are entered, the appropriate section of the QA/Field Data Sheet is initialed and dated. Chris Nash is assisted in data entry verification by Andy Chapman or a program volunteer. As data entry is verified, the entry in the database field entitled “ENTRYQA” is changed from a “No” (the default value) to a “Yes,” and the appropriate section of the QA/Field Data Sheet is initialed and dated.

Data Management: Electronic data from the stormwater samples will be maintained in an Excel spreadsheet by the DES Water Quality Planning Section. Data from this spreadsheet will ultimately be imported into the DES Shellfish Program Shoreline database. Electronic data from the ambient stations will reside in the DES Shellfish Program Water Quality database. Management of hardcopy data and documents is described in Section A9.

Data Security: All databases will be maintain on password protected computers. Hardcopy files will be stored in a secured office with a key-card system (6 Hazen Drive, Concord NH) to which only DES employees have access.

Data Analysis: The procedures for data analysis were described in Section A7.

C1 – Assessments and Response Actions

In order to determine that field sampling, field analysis and laboratory activities are occurring as planned, field staff and laboratory personnel shall meet, after the first sampling event, to discuss the methods being employed and to review the quality assurance samples. At this time all concerns regarding the sampling protocols and analysis techniques shall be addressed and any changes deemed necessary shall be made to ensure consistency and quality of subsequent sampling. Assessment frequencies and responsible personnel are shown in Table 6.

Table 14: Project Assessment Table

Assessment Type	Frequency	Person responsible for performing assessment	Person responsible for responding to assessment findings	Person responsible for monitoring effectiveness of corrective actions
Field sampling audit	Once after first sampling day	Phil Trowbridge Project Manager DES	Phil Trowbridge Project Manager DES	Phil Trowbridge Project Manager DES
Field analytical audit	Once after first sampling day	Phil Trowbridge Project Manager DES	Phil Trowbridge Project Manager DES	Phil Trowbridge Project Manager DES
NHDES Laboratory Services Fixed Lab	Weekly	Rachel Rainey Lab QA/QC Officer NHDES	Rachel Rainey Lab QA/QC Officer NHDES	Rachel Rainey Lab QA/QC Officer NHDES

Based on EPA-NE Worksheet #27b.

Field Sampling Audit: QAPP deviations and project deficiencies determined during the field sampling assessment will be evaluated for source of deviation and corrected with verbal communications in the field and documented in field log books. Any necessary written/structural changes will be made through a revision of the SOP for that activity (and this QAPP). Field sampling activities will be monitored to determine compliance.

Field Analytical Audit: QAPP deviations and project deficiencies determined during the field analytical assessment will be evaluated for source of deviation and corrected with verbal communications in the field and documented in field log books. Any necessary written/structural changes will be made through a revision of the SOP for that activity (and this QAPP). Field analytical activities will be monitored to determine compliance.

NHDES Laboratory Services Fixed Laboratory Audit: QAPP deviations and project deficiencies determined during the NHDES Laboratory Services fixed laboratory assessments will be addressed immediately. Replicates and critical range tables will be checked with data to determine if sources of error exist. Any deviations in results will be addressed in both written and verbal formats, and future sampling will be monitored to verify that compliance is reached.

C2 – Reports to Management

The reports to management are summarized in the following table.

Table 15: Reports to Management

Report	Frequency	Author	Recipient	Action expected of recipient
Quarterly reports to the NH Estuaries Project	Quarterly from 6/30/02 until 12/31/02	Chris Nash	Cynthia McLaren, Director, NHEP	Review work completed compared to expected schedule in contract.
DRAFT TMDL Report for Hampton Harbor	One DRAFT report, expected by 12/31/02	Phil Trowbridge	Alison Simcox, TMDL Coordinator, EPA Reg I	Review and comment on TMDL study and implementation plan
Final TMDL Report	One report, expected by 5/1/03	Phil Trowbridge	Alison Simcox, TMDL Coordinator, EPA Reg I	Approve TMDL study and implementation plan

D1 – Data Review, Verification and Validation

The Project QA Officer will be responsible for conducting the following data review tasks. The QA Project Officer will prepare a memorandum to the Project Manager documenting the completion of the review and any inconsistencies between the actual methods and the QA Project Plan that were identified.

Table 16: Data Review, Verification, and Validation Tasks

Project Activity	Review Activities
Sampling Design	1. Check that sampling strategy conforms to QAPP. 2. Check that selection of sampling locations by field teams matches QAPP.
Field Sampling	1. Check use of prescribed procedures and equipment. 2. Check that proper containers and preservatives were used.
Field Documentation	1. Check that proper data entry procedures were used for field data sheets. 2. COC forms: Check that forms are properly completed, signed, and dated during transfer. Check that all samples were assigned identification numbers and accounted for. 3. Check that all samples were properly packaged.
Field Screening and Analytical Testing Data	1. Check that field instruments were properly calibrated. 2. Check calculations, transcriptions, and reporting units for field measurements recorded on data sheets.
Laboratory	1. Check that all requested data is reported, and is in compliance with contract analytical specifications and methods. 2. Check that COC documentation from laboratory matches COC field data sheets. 3. Check that sample temperatures were <10^{o}C upon receipt at laboratory. 4. Check that holding times were not exceeded. 5. Check that QC samples (e.g., duplicate samples) were analyzed. 6. Check that trip, method, and instrument blanks are not contaminated.
Project file	Check that the project file at the DES Water Quality Planning Section office contains all field and laboratory data for the project.

D2 – Verification and Validation Procedures

The Project QA Officer will be responsible for evaluating results from QC samples and determining whether data quality objectives have been met. Specifically, the Project QA Officer will

- Calculate the RPD between duplicate samples to determine if the data quality objectives for precision were met (for more details see Section A7 and B5).
- Review the sign-off blocks on the field data sheets to determine whether the data entry procedures from Section B10 were followed.
- Calculate the data completeness for the project and compare it to the data quality objective of 67%.

The Project QA Officer will prepare a memorandum for the Project Manager with findings regarding the quality of the data for the project.

D3 – Reconciliation with User Requirements

The Project Manager will be responsible for reconciling the results from this study with the requirements of the TMDL (the ultimate use of the data). Results that are qualified by the Project QA Officer may still be used in the TMDL report if the uncertainty in the results is clearly reported to decision-makers. Because the stormwater samples will be collected synoptically during specific storms, it will not be possible to collect additional samples to confirm any questionable results. To that end, the Project Manager will:

1. Review data with respect to sampling design.
2. Review the Data Verification and Validation reports from the Project QA Officer.
3. If any of the results have been qualified by the Project QA Officer, calculate the cumulative error in the loading estimates to determine whether data can be used to for the TMDL report.
4. Draw conclusions from the data.

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Appendix A

Assessment of the Accuracy of Various Discharge Estimation Methodologies

Prepared by Chris Nash, NHDES Shellfish Program Manager (April 2002)

INTRODUCTION

The NHDES Shellfish program routinely performs shoreline surveys for pollution sources in shellfish growing waters. These surveys require an assessment of bacterial loading from potential pollution sources. Loading assessments typically involve not only collection of water samples for bacterial analyses, but also estimation of discharge.

Estimates of discharge from potential pollution sources, many of which are stormwater pipes, can be made using a variety of methodologies. Perhaps the most simple, direct, and accurate is the volumetric method, in which the time required to fill a container of known volume is measured. Unfortunately, this method is often impractical, as most stormwater pipes lack the clearance under the pipe required to capture the flow. Therefore, other means of estimating discharge must be employed.

The purpose of this study is to assess the relative accuracy of a variety of discharge estimation techniques that could be used in NHDES Shellfish Program shoreline surveys. The results of the study will enable NHDES to select discharge estimation methodologies appropriate to the intended use of the data, and to report on the quality of the discharge estimates generated to potential data users.

Study Design and Methods

The NHDES Shellfish Program initiated a comparative study of discharge estimation methodologies in the spring of 2002. A group of circular pipes of varying diameter, on which a number of discharge measurements would be made under a variety of flow conditions, were identified by program staff (Appendix 1). In order to allow for volumetric measurements of discharge, only pipes with more than six inches of underneath clearance were selected for the study.

On a number of days during both dry and wet weather, discharge estimates were made using some/all of the following methodologies:

Volumetric: The time required to fill the container of known volume (2, 5, and 22 gallon containers are used, as appropriate) is measured three times with a stopwatch that reads to the nearest 0.01 second. The average of the three observed times is used to calculate discharge.

Depth/Diameter/Velocity (with current meter): discharge calculated by the following equation:

$$Q = A*V$$

Where Q = discharge in ft^3/sec
A= cross sectional area of the filled portion of a circular pipe, ft^2
V= velocity of flow, ft/sec

Cross sectional area of the filled portion of the circular pipe is derived from the following equation:

$$A = R^2 \cdot \cos^{-1}\left(\frac{R-h}{R}\right) - (R-h)\sqrt{2Rh-h^2}$$

Where A= cross sectional area of the filled portion of the pipe, ft^2
R= radius of pipe, ft
h = depth of water in pipe, ft

In this method, velocity is derived using a flow meter per the manufacturer instructions. The DES Shellfish Program utilizes a "Global Flow Probe" from Global Water, Inc., which is accurate to 0.1 ft/sec. Three velocity measurements are made, and the average is used for the discharge calculation. Depth is measured with a wooden ruler or with a wire affixed to a combination square, to the nearest 1/8 inch.

Depth/Diameter/Velocity (with miniature float): when conditions preclude the use of a velocity meter (e.g., insufficient water depth), velocity must be estimated by using miniature floats. In this method, velocity is derived inserting miniature floats a known distance into the pipe, and observing the time required for the current to carry the float out of the pipe. Depending on the velocity, either a 4-ft or 8-ft rod is used to insert the float into the pipe. When the float is released into the flow, the time required for it to exit the pipe is measured. Three time measurements are made with a stopwatch that reads to nearest 0.01 second, and the average time is used to calculate velocity. Depth is measured with a wooden ruler or with a wire affixed to a combination square, to the nearest 1/8 inch. The same equations presented above are then used to estimate discharge.

For the field study, volumetric measurements were assumed to represent the true value of discharge at each site. The other methods were employed as site conditions allowed. For velocity measurements made with miniature floats, time required to travel over short (4-ft) and long (8-ft) distances were made to determine the most appropriate method.

Error Estimations

To examine how errors in water depth and velocity measurements might affect discharge estimations, sensitivity analyses were performed. Errors in water depth measurements were modeled for three hypothetical flow conditions:

- low flow (1 inch of water in the pipe, velocity of 2 ft/sec)
- moderate flow (3 inches of water in the pipe, velocity of 4 ft/sec)
- high flow (4 inches of water in the pipe, velocity of 7 ft/sec)

For each flow condition, discharge was calculated for 1, 2, 3, and 4-foot pipes the given depth and velocity. Errors in water depth measurement were simulated at 1/8" intervals, up to 0.50 inches. The resulting deviations from the true discharge value, expressed as a percentage of the true discharge value, are presented in Table 1.

Table 1: Percent Deviation from True Discharge due to Errors in Water Depth Measurement

Flow Condition	Pipe Diam (in)	Depth 1/8" off (%diff)	Depth ¼" off (%diff)	Depth 3/8" off (%diff)	Depth 1/2" off (%diff)
low flow water depth 1in, velocity 2fps	12	20.4	39.2	56.4	71.6
	24	20.5	39.4	56.6	71.8
	36	20.6	39.5	56.7	71.8
	48	20.6	39.5	56.7	71.9
moderate flow water depth 3in, velocity 4fps	12	6.1	12.1	18.0	23.8
	24	6.3	12.5	18.5	24.4
	36	6.3	12.6	18.6	24.6
	48	6.4	12.7	18.8	24.7
high flow water depth 4in, velocity 7fps	12	4.4	8.8	13.1	17.4
	24	4.6	9.2	13.7	18.1
	36	4.7	9.3	13.9	18.4
	48	4.7	9.4	13.9	18.4

Errors in velocity measurements were also modeled for the same three hypothetical flow conditions (low, moderate, and high flow). For each flow condition, discharge was calculated for 1, 2, 3, and 4-foot pipes at the given depth and velocity. Errors in velocity measurements were simulated at 0.1 ft/sec intervals up to 0.5 ft/sec (assuming use of an 8ft rod for the miniature float method, these deviations would result from errors in time measurement of 0.19-0.80 seconds under low flow, 0.05-0.22 seconds under moderate flow, and 0.01-0.07 seconds under high flow). The resulting deviations from the true discharge value, expressed as a percentage of the true discharge value, are presented in Table 2.

Table 2: Percent Deviation from True Discharge due to Errors in Velocity Measurement

Flow Condition	Pipe Diam (in)	V off by 0.1 fps (%diff)	V off by 0.2 fps (%diff)	V off by 0.3 fps (%diff)	V off by 0.4 fps (%diff)	V off by 0.5 fps (%diff)
low flow	12-48	5.0	10.0	15.0	20.0	25.0
moderate flow	12-48	2.5	5.0	7.5	10.0	12.5
high flow	12-48	1.4	2.9	4.3	5.7	7.1

These calculations show that the greatest error can be expected under low flow conditions. Somewhat less error can be expected for high flow conditions.

Field Measurement Results

A summary of actual discharge estimations on the sites depicted in Appendix 1 is presented in Table 3. All depth measurements in Table 3 were made with a wooden ruler. Differences in discharge measurements, expressed as a percentage of the volumetric measurement, are presented in Table 4.

Table 3: Discharge Measurements

DATE	SITE	PIPE DIA. (in)	WATER DEPTH (in)	VOLUMETRIC			DEPTH/DIAM./VELOCITY METHOD		
				2GAL (GPM)	5 GAL (GPM)	22 GAL (GPM)	6-8ft ROD (GPM)	4ft ROD (GPM)	METER (GPM)
3/15/02	Blackwater	48	3			~1320		1113.93	
3/19/02	Hubbard Rd	24	0.5	7.20				7.24	
3/19/02	Hubbard Rd	18	0.375	2.06				5.03	
3/19/02	Upp. Spur Rd	18	0.75	24.00				28.27	
3/19/02	Low. Spur Rd	30	0.75	18.00				48.86	
3/25/02	Upp. Spur Rd	18	1	65.34	62.46			99.09	
3/25/02	Low. Spur Rd	30	0.75	25.46				62.80	
3/25/02	Sawyer Mills	12	0.75		23.23			51.64	
3/26/02	Hubbard Rd	24	1.75		108.30		145.12	164.47	161.24
3/26/02	Hubbard Rd	18	0.875	26.07			41.52	46.35	
3/26/02	Upp. Spur Rd	18	3.25			519.69	715.71	660.13	743.98
3/26/02	Low. Spur Rd	30	1	113.92		113.05	95.76	95.08	111.08
3/26/02	Sawyer Mills	12	1		43.44		84.17	75.48	64.11
4/1/02	Hubbard Rd	24	1.25		61.64		86.57	82.09	
4/1/02	Hubbard Rd	18	0.5	9.31			14.28	14.65	
4/1/02	Upp. Spur Rd	18	2.875			393.05	450.99	482.86	541.68
4/1/02	Low. Spur Rd	30	0.875			74.49	67.03	80.33	
4/1/02	Sawyer Mills	12	0.75		23.57			47.97	

Table 4: Percent Differences Between Volumetric and Depth/Diameter/Velocity Discharge Measurements

DATE	SITE	FLOW COND.	PIPE DIA. (in)	WATER DEPTH (in)	VOLUM. METH. (GPM)	DEPTH/DIAM./VELOCITY METHOD		
						6-8ft ROD (%diff)	4ft ROD (%diff)	METER (%diff)
3/15/02	Blackwater	Mod	48	3	~1320		~21	
3/19/02	Hubbard Rd	Low	24	0.5	7.20		8	
3/19/02	Hubbard Rd	Low	18	0.375	2.06		-126	
3/19/02	Upp. Spur Rd	Low	18	0.75	24.00		-10	
3/19/02	Low. Spur Rd	Low	30	0.75	18.00		-92	
3/25/02	Upp. Spur Rd	Low	18	1	65.34		-70	
3/25/02	Low. Spur Rd	Low	30	0.75	25.46		-74	
3/25/02	Sawyer Mills	Low	12	0.75	23.23		-109	
3/26/02	Hubbard Rd	Mod	24	1.75	108.3	-26	-43	-40
3/26/02	Hubbard Rd	Mod	18	0.875	26.07	-66	-86	
3/26/02	Upp. Spur Rd	Mod	18	3.25	519.69	-37	-26	-43
3/26/02	Low. Spur Rd	Mod	30	1	113.05	27	28	16
3/26/02	Sawyer Mills	Mod	12	1	43.44	-82	-64	-39
4/1/02	Hubbard Rd	Mod	24	1.25	61.64	-40	-33	
4/1/02	Hubbard Rd	Mod	18	0.5	9.31	-53	-57	
4/1/02	Upp. Spur Rd	Mod	18	2.875	393.05	-15	-23	-38
4/1/02	Low. Spur Rd	Mod	30	0.875	74.49	10	-8	
4/1/02	Sawyer Mills	Mod	12	0.75	23.57		-104	

Discussion

Low flow conditions were encountered on 3/15, 3/19, and 3/25. Some rather large differences in discharge estimates were observed, and these are likely due to difficulties with getting an accurate velocity measurement. On these low flow days, water depths are too low for use of a current meter, and a miniature float method of determining velocity must be used. The velocity measured by the miniature float only represents velocity in the top center of the flow. It does not accurately represent flows on the bottom and sides of the pipe, which are likely slower due to friction and probably represent a significant amount of the flow under shallow depth conditions. The float method likely overestimates velocity, which would explain why discharge estimates from depth/diameter/velocity method are higher than the volumetric measurements.

Higher flows were encountered on 3/26, following a one-inch rainstorm. Observed differences on this day were generally greater in the smaller pipes. Most of the differences observed were likely due to difficulties in accurately measuring water depth.

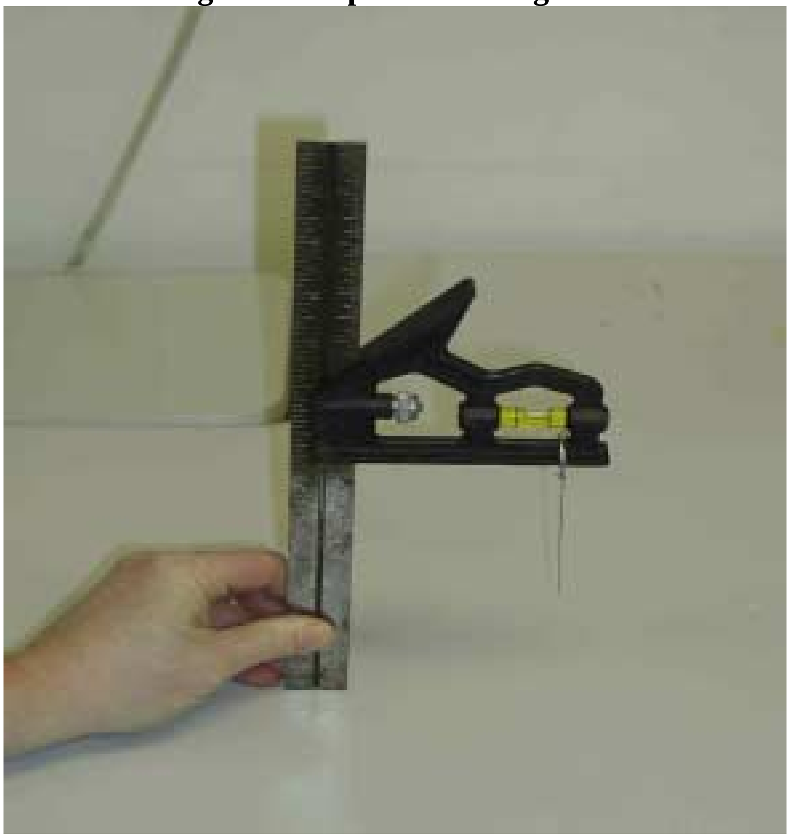
For all measurements except 4/1 (moderate flow following a 0.75-inch storm), water depths were measured using a wooden ruler. At high velocities, errors in estimating water depth may be introduced as the flow "runs up" the ruler, making an accurate measurement difficult. In light of this, and in light of the error estimations presented in Table 1, an alternative tool for reducing error in water depth measurement was developed. By securing a 3-inch long piece of relatively stiff (19 gauge or thicker) galvanized wire to a combination square (Figure 1), much of the error can be eliminated. With the bottom of the combination square set in the deepest section of pipe, the wire can be situated on the upstream side of the flow and lowered to the water surface – this eliminates "run-up" and keeps the sampler's hands out of the water. Furthermore, the ruler on the combination square provides a convenient way to measure depth, and the bubble level helps ensure an accurate measurement.

For the 4/1 measurements, both depth measurement methodologies were employed. The results (Table 5) suggest that the combination square method generally provides for better discharge estimates, in some cases dramatically so. For some of the pipes, the estimate of depth varied by as much as 3/8 of an inch (which can result in errors of 13% to 57%, based on the figures in Table 1).

Table 5: Percent Differences Between Volumetric and Depth/Diameter/Velocity Discharge Measurements Utilizing Two Different Depth Measurement Methods

			DEPTH WITH RULER METHOD				DEPTH WITH COMB.SQUARE METHOD			
				DEPTH/DIAM./VELOCITY METHOD				DEPTH/DIAM./VELOCITY METHOD		
SITE	PIPE DIA. (in)	VOLUM. METH. (GPM)	WATER DEPTH (in)	6-8ft STICK (%diff)	4ft STICK (%diff)	METER (%diff)	WATER DEPTH (in)	6-8ft STICK (%diff)	4ft STICK (%diff)	METER (%diff)
Hubbard Rd	18	9.31	0.5	-53	-57		0.375	2	-3	
Upp. Spur Rd	18	393.1	2.875	-15	-23	-38	2.500	6	-3	-12
Low. Spur Rd	30	74.49	0.875	10	-8		0.750	28	14	
Sawyer Mills	12	23.57	0.75		-104		0.625		-55	

Figure 1: Depth Measuring Tool



Conclusions

Volumetric measurements are always preferable, but rarely feasible in the field setting typically encountered by NHDES Shellfish Program staff.

At low flows and shallow depths, errors in the cross sectional area method can be very large, and are most likely due to erroneous velocity measurements (due to variation in velocity due to friction with the pipe). Improving the accuracy of velocity measurements under such conditions is very difficult. Errors can exceed 75% of the true value.

At higher flows and deeper depths, errors in the cross sectional area method are more likely due to erroneous depth measurements, which can be very difficult to accurately obtain under high velocity conditions. Variation in velocity at different parts of the pipe may also account for some of the error. Errors at moderate/high flows can be 25% or less; however, careful depth measurements can dramatically improve results, perhaps reducing error to 15% or less.

When using a miniature float to determine velocity, better results are generally produced by using a longer rod (8 ft versus 4 ft); however, differences in error between the two methods were not dramatic, and some site conditions require the use of a shorter rod.

The current meter did not produce consistently better results than the miniature float method; however, relatively few comparisons between these methods were made because shallow water depths precluded the use of the current meter. One can expect that as velocities increase with high flow conditions, the chances of significant error using the float method are likely to increase. Furthermore, high flow conditions may make using the float method difficult, perhaps even dangerous. Thus, it may be best to use a current meter under high flow conditions.

Depth measurements should be made using the combination square/wire tool, rather than regular wooden rulers. This tool seems to give better depth measurements, and much better discharge estimates.

Based on the hypothetical error calculations in Tables 1 and 2, as well as the field results, the following errors in discharge measurements, expressed as a percentage of the true value, can be expected (assume 24" diameter pipe):

	Low Flow	Moderate Flow	High Flow
Error due to Depth (w/ comb. Square, 1/8")	20.5	6.3	4.6
Error due to Velocity (w/ meter, 0.1 f/sec)	5	2.5	1.4
Total Error	21	7	5

Note: Total error calculated using standard error propagation methods for independent, random errors in a simple product without coefficients:

$$E_{flow} = [E_a^2 + E_v^2]^{1/2}$$

where
E_{flow} is the total percent error in the flow estimate;
E_a is the percent error in the flow estimate due to uncertainty in the depth measurement;
E_v is the percent error in the flow estimate due to uncertainty in the velocity measurement.

If water depths are too shallow and a float must be used, the velocity measurements are likely to be more in error. Assuming a "high-end" error of 0.5 ft/sec, the following errors in discharge measurements, expressed as a percentage of the true value, can be expected:

	Low Flow	Moderate Flow	High Flow
Error due to Depth (w/comb. Square, 1/8")	20.5	6.3	4.6
Error due to Velocity (w/ float, 0.5 f/sec)	25	12.5	7.1
Total Error	32	14	8

Attachment A

Study Sites

Blackwater Brook Culvert: this 48 inch concrete culvert is located off Blackwater Road in Dover, NH. Elevated flows due to beaver activity upstream make volumetric flow measurements at this site impractical, as flows of 25 gallons per second and higher are commonly observed. Access is not restricted by tides.

Hubbard Road: these 18 inch and 24 inch concrete stormwater pipes drain to a stormwater pond in a Hubbard Road subdivision in Dover, NH. Access is not restricted by tides. Volumetric measurements can be made with 2, 5, and 22 gallon containers on the 24 inch pipe, and with a 2 gallon container on the 18 inch pipe.

Lower Spur Road Culvert: this 30-inch concrete culvert runs underneath the lower section of Spur Road in Dover, NH, and drains stormwater to the tidal portion of the Bellamy River. Access is not restricted by tides. Volumetric measurements are possible with 2 and 22 gallon containers.

Upper Spur Road Culvert: this 18-inch corrugated black plastic culvert runs underneath the upper section of Spur Road in Dover, NH, and drains stormwater to the tidal portion of the Bellamy River. Access at high tide is limited. Low tide volumetric measurements are possible with 2, 5, and 22 gallon containers.

Sawyer Mills: this 12 inch stormwater pipe discharges directly to the Bellamy River adjacent to the Sawyer Mills apartment building in Dover, NH. Access is not restricted by tides. Volumetric measurements are possible with 2, 5, and 22 gallon containers.

APPENDIX B

Standard Operating Procedure for Culvert Flow Measurements

A. Equipment

Global Water FP101-FP201 Global Flow Probe

Specifications:

Velocity Measurement: Propeller
Accuracy: ±0.1 ft/s

Calibration:

This unit only needs to be calibrated if the batteries have been changed. If you did not change the batteries, skip to Section B on the next page.

The computer's set-up sequence is entered automatically when the batteries are changed. You can also enter the set-up sequence at any time by holding both buttons simultaneously for 8 seconds.

- During the set-up sequence, all of the display segments are displayed first, and then "mi" appears for English units (ft/s) and "km " appears for metric units. The left button toggles between English and Metric units.
- Push the right button to enter "CAL "mode. This is your Flow Probe calibration function. Set the calibration at 33.31. **When you change your batteries, you must reset this number**. Pushing the left button increases the number when the arrow points up and decreases the number when the arrow points down.
- To continue the set-up sequence after you have set your English or Metric calibration:
    - Push the Right button-be sure "CAD "is not displayed.
    - Push the Right button-SLEEP will appear. If you are not using your Flow Probe for 1-2 months, leave it in this SLEEP mode, to reduce battery drain.
    - Push the Right button-push the Left button to toggle between 24 hr and 12 hr clock.
    - Push the Right button-push the Left button to set HOUR (time of day).
    - Push the Right button-push Left to set the MINUTE (time of day).
    - Push the Right button-you are now out of Set Up and back in Velocity ("V"). Push the left button to toggle the bottom number between maximum ("mx") and average ("av") velocities. **Set the probe to record the average velocity.**

B. Measuring Flow from a Culvert:

1. Find downstream end of culvert. Record the culvert number (PS#) and the time (in military units) on the field data sheet.

2. Observe whether there is any flow in the culvert (based on eye observations only). **If there is no flow, record "no flow" in the comments section of the field data sheet, and skip to Step 6.** If the pipe is flowing, go to Step 3.

3. Observe whether the culvert is round or a box culvert (rectangular).

   a.) If the culvert is round, measure the diameter of the culvert to the nearest ½ inch and record this value on the field data sheet.
   b.) If the culvert is better approximated by a box culvert (e.g., the bottom of the pipe is full of sediment, or the pipe is deformed or not circular), measure the width of the culvert at the water height to the nearest ½ inch. Record in the "Comments" section of the field data sheet, that the culvert is a "box culvert with width XXX inches".

4. Measure the water depth in the center of the culvert.

   a) If the water depth is less than 8 inches, use the depth measuring tool made out of a combination square (see Appendix A for a description of this tool).
   i. Place the "ruler" end of the combination square down to the bottom of the pipe in the middle of the pipe with the arm of the tool facing upstream.
   ii. Slide the arm down the ruler until the metal wire on the end of the arm is just touching the surface of the water. Be sure to level the device using the bubble level.
   iii. Lock the arm in place by twisting the clamp and then remove the tool from the flow.
   iv. Read the value on the ruler at the bottom of the arm to the nearest 1/8th of an inch and **then subtract 3 inches (to account for the length of the wire).**
   v. Record this depth on the field data sheet to the closest 1/8 inch.

   b) If the water depth in the pipe is more than 8 inches deep, use a collapsible yardstick
   i. Measure the total height of the entire culvert to the closest ¼ inch.
   ii. Measure the distance between the water level and the top of the pipe to the closest ¼ inch.
   iii. Subtract the second measurement from the first measurement. This is the water depth.
   iv. Record this value on the field data sheet to the closest ¼ inch.

5. Measure the average velocity of flow.

a.) If the water depth is greater than 2 inches deep at the center of pipe, use the current meter.

i. Make sure the Flow Probe 's propeller turns freely by blowing strongly on the prop. Remove any debris that is caught in the propeller.
ii. Make sure the probe display shows "V" for velocity mode, "av" for averaging mode, and "mi" for English units (ft/s). If not, see the calibration section to set up the probe.
iii. Insert the propeller end of the probe into the middle of the flow you wish to measure. **Point the arrow inside the prop housing downstream**.
iv. **With the propeller placed at your measuring point in the flow, push both the right and left buttons simultaneously for approximately 1 second and then release them.** This will clear the computer and reset the average velocities. **Tell your partner at the time you reset the meter and have them tell you when 30 seconds have elapsed since the reset.** The Flow Probe uses true velocity averaging. When the average velocity is zeroed by pushing both buttons, a running average is started. As long as the probe remains in the flow, the averaging continues. One reading is taken per second, and a continuous average is displayed. For example, after 10 seconds, 10 readings are totaled and then divided by 10 and this average is displayed.
v. For small streams and pipes, the probe can be moved slowly and smoothly throughout the flow during average velocity measurement. Move the probe smoothly and evenly back and forth from top to bottom of the flow so that the probe stays at each point in the flow for approximately the same amount of time. Keep moving the probe for 30 seconds to obtain an accurate average value that accounts for surging. (Move the probe as if you were spray painting and attempting to get an even coat of paint over the entire surface.)
vi. After 30 seconds (as timed by your partner), **read the SMALLER number (the average velocity) on the lower right corner of the screen**. Have your partner record the average velocity value on the data sheet in ft/s. Do not remove the probe from the flow when you read the measurement.
vii. Repeat the velocity measurement for a total of three times.
viii. If the flow is so slow that no velocity reading is displayed, you cannot use the probe. Try to measure flow using the miniature float method (see Step 4B in below)
ix. Record the time that you completed your measurements on the field data sheet.

b.) If the water depth is less than 2 inches deep at the center of the pipe or if the velocity is too low to use the probe, use the miniature float method.

i. Place a small foam float on the end of a flat piece of wood of known length (either 4 feet or 8 feet long).
ii. Balancing the float on top of the plank, insert the plank into the culvert above the flowing water (with the float on the end inserted into the culvert first). Move the plank all the way into the culvert until the end without the float is flush with the end of the culvert.
iii. Count down out loud "3-2-1-go" and then turn the plank over to drop the float into the flow. The other team member will start a stopwatch at the time that the float is dropped. You may need to shake the rod to get the float to fall off if the pieces are wet.
iv. Watch the end of the pipe and say "stop" when the float reaches the end of the pipe. The team member with the stopwatch will stop the timer at that time. Record the time of travel for the float on the data sheet.
v. Repeat this measurement for a total of three times.
vi. On the field data sheet, circle the length of rod used for the measurement. *You should always start with the 4 foot rod because it is easier. However, if the time of travel with the 4 foot rod is less than 1 second, you should switch to the 8 foot rod.*
vii. Record the time that you completed your measurements on the field data sheet.

6. Record an comments or observations about the flow measurement in the final column of the field data sheet.

C. Quality Control/Quality Assurance:

For quality assurance purposes, duplicate analyses are required on at least ten percent (10%) of all velocity/depth measurements collected. For every 10th measurement of velocity and depth, duplicate the velocity and depth measurements and record them on the worksheet. Each field data sheet has 11 rows. The last row of every datasheet should be a duplicate measurement of the previous row.

D. Calculating Flow from Field Measurements

Stormwater flux will be calculated by the following equation:

$$Q = A \cdot V$$

Where,
Q = discharge in ft^3/sec
A = cross sectional area of the filled portion of a circular pipe, ft^2
V = velocity of flow, ft/sec

Cross sectional area of the filled portion of the circular pipe is derived from the following equation:

$$A = R^2 \cdot \cos^{-1}\left(\frac{R-h}{R}\right) - (R-h)\sqrt{2Rh-h^2}$$

Where
A= cross sectional area of the filled portion of the pipe, ft^2
R= radius of pipe, ft
h = depth of water in pipe, ft

Cross sectional area of the filled portion of a box culvert is:

$$A = W \cdot h$$

Where,
A= cross sectional area of the filled portion of the pipe, ft^2
W = width of box culvert at the water level, ft
h = depth of water in pipe, ft.

NHDES SHELLFISH PROGRAM
ROUTINE MONITORING QA/FIELD DATA SHEET

Run (circle 1) Great Bay Little Harbor Atl.Coast Rye Harbor
Hampton Harbor Atl. Coast (Boat) Other (specify):________________________

Funding (circle 1) DHHS NHEP DES OTHER (specify)______________

Sampling Day Info. Samples Collected by:__________________ Collection Date:____________ No. Sites Sampled:________

Air Temp (^{o}C):______ Weather Conditions: ____

Wind Direc (degrees)______ Wind Speed (circle 1) calm 0-5mph 5-10mph >10mph

Portland Low Tide Time_________ LT Height_________ Prev. HT Height_________

Chain of Custody Transported to ____________________ by _________________________ on _______________________
(name/org.) (name) (date)

Transported to ____________________ by _________________________ on _______________________
(name/org.) (name) (date)

Lab QA Delivery Date:______________ Delivery Time:_________________ Delivery Temp.______________°C

Samples acceptable? (yes/no)__________ Samples accepted by:_________________________________

If no, state problem:____

Analysis Date:____________________ Analysis Time:______________ Analysis Temp.________°C

Analyst:_________________________ Report Verifier:________ Date of Report:__________________

Analysis Method (circle one) MPN(LST-EC) MPN(A1) Plate Count

This QA sheet corresponds to and accompanies Lab #'s:______________through____________________

Data Entry Data Entered by________________________________ Date________________

Entry Verified by_______________________________ Date________________

Entry Verified by_______________________________ Date________________

SHELLFISH GROWING WATER ANALYSES REPORT SHEET

DES Laboratories, 6 Hazen Drive, Concord, NH 03301

Station	Collect. Time	WTemp (°C)	Lab #	FC #/100ml	Salinity (ppt)	PH	Wildlife	Other Activities
DUP								DUPLICATE OF PREVIOUS

NH DES LABORATORY SERVICES LOGIN AND CUSTODY SHEET
(Laboratory Policy: Samples not meeting method requirements will be analyzed at the discretion of the NH DES Laboratory.)

Program / Client ID: , In-House, OSA, Pool, Special, Swim, VLAP, Other:_________ EPA # / Project #:_05-0025210__

System Name:_____ _________________ Site / Town:_ Hampton Harbor TMDL Study Contact:_Phil Trowbridge 271-8872_______

Comments:_ _____________________________ Collected By & Phone# _________________________________

Sample Location /ID	Date/Time Sampled	# of Containers	Matrix	FC Counts										*Other / Notes*	Lab ID # (For Lab Use Only)
			AQ												
			AQ												
			AQ												
			AQ												
			AQ												
			AQ												
			AQ												
			AQ												
			AQ												
			AQ												
DUP			AQ											Duplicate of Previous	

Relinquished By____________________Date and Time__________________Received By____________________

Relinquished By____________________Date and Time__________________Received By____________________

Relinquished By____________________Date and Time__________________ **Received For Laboratory By______________**

Section No.: 22.0
Revision No.: 1
Date: 1-17-01
Page 1 of 1

Matrix: A= Air S= Soil AQ= Aqueous (Ground Water, Surface Water, Drinking Water, Waste Water) ❒ Other: ____AQ____________

Page ______ of _______ Data Reviewed By_____________________________ Date______________

NHDES STORMWATER FLUX FIELD DATA SHEET

Project: Hampton Harbor TMDL Stormwater Monitoring **Date**:____________ **Field Team/Staff**: ______________________________

Current Meter Type and Serial #: __________________ **Data Entry by**: ______ **Entry Verified by**: _____ **Project Manager**: _____
_

PS#	Time Start	Diam (in)	Depth (in)	**Flow Measurements** *Fill in either velocity by current meter (V) or time of travel for float (T).*			Rod Length	Time Stop	Comments
				V= ft/s	V= ft/s	V= ft/s	N/A		
				T= s	T= s	T= s	4 ft or 8 ft		
				V= ft/s	V= ft/s	V= ft/s	N/A		
				T= s	T= s	T= s	4 ft or 8 ft		
				V= ft/s	V= ft/s	V= ft/s	N/A		
				T= s	T= s	T= s	4 ft or 8 ft		
				V= ft/s	V= ft/s	V= ft/s	N/A		
				T= s	T= s	T= s	4 ft or 8 ft		
				V= ft/s	V= ft/s	V= ft/s	N/A		
				T= s	T= s	T= s	4 ft or 8 ft		
				V= ft/s	V= ft/s	V= ft/s	N/A		
				T= s	T= s	T= s	4 ft or 8 ft		
				V= ft/s	V= ft/s	V= ft/s	N/A		
				T= s	T= s	T= s	4 ft or 8 ft		
				V= ft/s	V= ft/s	V= ft/s	N/A		
				T= s	T= s	T= s	4 ft or 8 ft		
				V= ft/s	V= ft/s	V= ft/s	N/A		
				T= s	T= s	T= s	4 ft or 8 ft		
				V= ft/s	V= ft/s	V= ft/s	N/A		
				T= s	T= s	T= s	4 ft or 8 ft		
DUP				V= ft/s	V= ft/s	V= ft/s	N/A		Duplicate of previous reading.

Appendix C

Appendix C: SOP for Flow Measurements

2002 TMDL Stream Flow Determinations SOP

Equipment: Marsh-McBirney Model 2000 Flo-Mate, Flow field sheet
Velocity Measurement: Electromagnetic
Zero Stability: +/- 0.05 ft/sec
Accuracy: +/- 2% of reading + zero stability
Range: -0.5 to +19.99 ft/sec (-0.15 m/sec to 6 m/sec)

Calibration:

1. Flow meter calibration shall occur before the first measurement of the day, after the last measurement of the day and after any battery change.

2. Turn meter on and look for 'low battery' display. If display does not come on, proceed as follows. If light comes on, change batteries, then proceed with the following procedures. If you get a message on the screen that says "**NOISE - - -"** there is excessive electrical noise (such as from high voltage power lines) that could interfere with the readings. In such case it may be necessary to take flow readings at another location.

3. Set meter reading to **'time constant filtering" (rC)** by pressing the up and down arrow keys at the same time until the screen shows "rC". Set the time to **5 seconds** by pressing either the up or down arrow key.

4. Fill a 5 gallon bucket with water from stream. Insert the velocity probe into bucket **keeping it at least 3 inches away from the sides and bottom of the bucket**. To make sure the water and probe are motionless, **wait 10 minutes** after you have positioned the sensor before taking any zero readings. **Clear the meter reading by pressing the On/C key** and check for zero reading (no flow should be going on in bucket, thus zero reading). Based on a rC filter value of 5 seconds, **zero stability is +/- 0.05 ft/sec**. If the reading is outside of this range, see the manual for "Zero Adjust" procedures.

Quality Control/Quality Assurance:

For quality assurance purposes, duplicate analyses are required on at least ten percent (10%) of all incremental velocity/depth measurements collected as part of each flow measurement event. For every set of 10 increments where velocity and depth are recorded, duplicate the velocity and depth measurements for one full increment *(D_b, D_m, D_e, and V)* and record them on the worksheet. Quality control shall be based on a comparison of flows calculated for each increment (Velocity x Area of increment where the area is equal to the average of the depths at the beginning and end of the increment times the width of the increment) and should be less than 10%. If greater than 10%, repeat the measurements and recalculate the flow. The flow for an increment may be calculated using the following equation:

$$\text{Flow for an increment (cfs)} = \text{Velocity (ft/sec)} \times \text{Increment Width (ft)} \times \frac{[D_b + D_m + D_e]\ \text{(ft)}}{3}$$

Where:

D_b= depth at the beginning of the increment
D_m= depth at the middle of the increment
D_e= depth at the end of the increment.

Measuring Stream Channel Flow:

1. Select an area of the stream in which to measure flow (area near staff gauge is usually selected). Guidelines for site selection include the following:

- The channel should have as much straight run as possible. Where the length is limited, the straight length upstream from the selected location should be twice the downstream straight length.
- The channel should be as free as possible from flow disturbances.
- The flow should be free from swirls, eddies, vortices, backward flow or dead zones.
- Avoid areas immediately downstream from sharp bends or obstructions.
- Avoid converging or diverging flow or vertical drops
- Avoid areas immediately downstream of a sluice gate or where the channel empties into a body of stationary water.
- The stream bottom should be relatively flat and free of obstructions (large rocks, plants). Clear them if necessary.

2. Measure the width of the stream from bank to bank using a measuring tape. Record the total width of the stream on the worksheet.

3. Divide the total stream width by 20 and round down to the nearest one half foot. For example, if the stream width is 60 feet, the largest size increment would be 3 feet (60/20). If the stream width is 46 feet, the largest size interval would be 2.0 feet (46/20 = 2.3 feet which rounds down to 2.0 feet). For intervals of less than 10 feet, use an interval of 0.5 feet. Using the measuring tape, break the stream width into segments at that are no larger than the maximum size interval calculated above.

4. Set the meter to record in **feet per second (ft/s)** by pressing down on the ON/C and OFF keys simultaneously until FT/S appears on the display.

5. Set meter reading to **'Fixed Point Average"** by pressing the up and down arrow keys at the same time until the screen shows "**FPA**". In the FPA mode, the meter will display the average of velocities over a fixed period of time. **Set the averaging time to 30 seconds** by pressing either the up or down arrow key.

6. Take a **depth reading at the <u>beginning, middle and end</u> of each increment** across the stream, starting at river right and ending at river left. Record these depths on the flow sheet. Measure the velocity at the midpoints of each increment at the same time its dept is being measured. To do this, attach the velocity probe to either a top-setting or bottom setting rod. **For increments with a depth less than 2 feet at the point where a velocity reading will be taken**, point the velocity probe upstream and position the center of the probe at a depth which is 60% of the way down from the surface of the stream, and 40% of the way above the sediments. When

taking velocity measurements, **stand an arm's length away facing perpendicular to the flow, to the side, and downstream of the flow meter.** This is very important to avoid interfering with the velocity measurements. **Clear the display by pressing the ON/C button**. **Allow one full averaging period to pass. Record the velocity on the flow sheet after the second, 30 seconds averaging periods has elapsed.**

7. Move to the middle of the next increment and Step 8. **For increments where the middle depth exceeds 2 feet, take velocity measurements at depths equal to 20 % and 80% from the surface** and record these on the worksheet. Continue until velocity readings are collected for entire stream width.

8. Take a reading off the staff gauge in the stream if available, recording this number in the appropriate column on the field data sheet and the time.

<u>Measuring Stream Flow from a Culvert:</u>

1. Find downstream end of culvert

2. Using a yardstick or other measuring device, take a depth reading in the center of the culvert invert. Record this on the field data sheet.

3. Next, take a measure of the width of the entire culvert. Record this on the data sheet.

4. Next, place the velocity probe into the flow of the water in the center of the culvert invert. Take a fixed point averaged velocity reading as described above. Record in appropriate column on field data sheet.

5. Take a reading off the staff gauge in the stream below the culvert, and record in appropriate column of the field data sheet.

<u>Volumetric Approach:</u>

1. Where flow is insufficient to make a measurement using the Flo-Mate 2000 and there is a spot where all (+/-) of the flow may be collected into a bucket or some other container, a volumetric approach will be used.

2. Collect the flow for a set period of time, recording the volume of water collected and the time period of collection. The period of collection should be greater than 10 seconds to minimize error.

3. If a small portion of flow is escaping collection, the two members of the flow team will independently estimate the percentage of seepage. The average of the two trials will be used to adjust the final flow.

4. Repeat this procedure a minimum of three times. The average flow from all trials will be used as the flow at the site.

Appendix D

Bacteria and Flow Sampling Data

Table D1: Fecal coliform sample concentrations from Hampton Harbor TMDL wet weather sampling program.

Station	Date	Time	Water Temp (degC)	Fecal Coliforms (cts/100ml)	FC Qualifier	Field Comments
HHPS015	7/23/2002	15:46	26	800		none
HHPS015	7/23/2002	16:27	25	1,000		none
HHPS015	7/23/2002	17:46	21	3,500		none
HHPS015	7/23/2002	18:31	21	700		none
HHPS015DUP	7/23/2002	16:28	25	1,600		Field duplicate for HHPS015 7/23/02 16:27
HHPS016	7/23/2002	15:48	22	200		none
HHPS016	7/23/2002	16:44	21	700		none
HHPS016	7/23/2002	17:55	22	1,400		Sample time missing from label. The time was taken from the field data sheet.
HHPS016	7/23/2002	18:38	22	4,400		none
HHPS055	7/23/2002	14:46	20	100	<	none
HHPS055	7/23/2002	16:00	24	100	<	none
HHPS055	7/23/2002	17:03	23	100		none
HHPS055	7/23/2002	18:06	23	100		none
HHPS056	7/23/2002	14:56	24	100	<	none
HHPS056	7/23/2002	16:03	24	100	<	none
HHPS056	7/23/2002	17:30	23	1,100		none
HHPS056	7/23/2002	18:10	23	1,100		none
HHPS056DUP	7/23/2002	18:14	NA	800		Field duplicate for HHPS056 7/23/02 18:10; sample bottle had the wrong station number, the station number was taken from the field data sheet.
HHPS063	7/23/2002	16:10	22	100	<	none
HHPS063	7/23/2002	18:16	21	200		none
HHPS066	7/23/2002	15:13	23	100	<	none
HHPS066	7/23/2002	16:20	25	17,000	>	none
HHPS066	7/23/2002	16:50	21	8,400		none
HHPS066	7/23/2002	17:40	24	7,500		none
HHPS066	7/23/2002	18:10	23	570		none
HHPS066	7/23/2002	18:50	23	8,800		none
HHPS067	7/23/2002	16:53	21	200		none
HHPS067	7/23/2002	17:45	25	8,600		none
HHPS067	7/23/2002	18:15	23	20,000	>	none
HHPS067	7/23/2002	18:55	24	9,000		none
HHPS067DUP	7/23/2002	18:15	23.5	20,000	>	Field duplicate of HHPS067 7/23/02 18:15
HHPS068	7/23/2002	15:02	25	100	<	none

Station	Date	Time	Water Temp (degC)	Fecal Coliforms (cts/100ml)	FC Qualifier	Field Comments
HHPS068	7/23/2002	16:10	NA	100		none
HHPS068	7/23/2002	16:37	24	20,000	>	none
HHPS068	7/23/2002	17:25	25	8,700		none
HHPS068	7/23/2002	18:00	24	200		none
HHPS068	7/23/2002	18:40	24	300		none
HHPS068DUP	7/23/2002	16:37	24	20,000	>	Field duplicate of HHPS068 7/23/02 16:37
HHPS069	7/23/2002	15:04	22	100	<	none
HHPS069	7/23/2002	16:09	NA	100	<	none
HHPS069	7/23/2002	16:36	24	20,000	>	Debris in water
HHPS069	7/23/2002	17:20	26	5,100		Oil sheen on water
HHPS069	7/23/2002	17:55	25	1,000		none
HHPS069	7/23/2002	18:35	24	700		none
HHPS070	7/23/2002	15:39	22	100		none
HHPS070	7/23/2002	16:10	21	100	<	none
HHPS070	7/23/2002	17:27	22	1,000		Sample is smelly and dirty
HHPS070	7/23/2002	18:25	22	1,700		RPD with field duplicate was 118%. Do not use for TMDL calculations.
HHPS070DUP	7/23/2002	18:25	NA	6,600		Field duplicate of HHPS070 7/23/02 18:25 RDP was 118%. Do not use for TMDL calculations.
HHPS071	7/23/2002	16:15	22	1,500		Sample is dirty
HHPS071	7/23/2002	17:30	22.5	1,500		none
HHPS071	7/23/2002	18:30	21.5	800		none
HHPS071DUP	7/23/2002	18:35	NA	800		Field duplicate of HHPS071 7/23/02 18:30
HHPS072	7/23/2002	16:20	18	14,800		none
HHPS072	7/23/2002	17:33	19	2,500		Sewer smell
HHPS072	7/23/2002	18:35	20	500		none
HHPS072DUP	7/23/2002	18:40	NA	500		Field duplicate of HHPS072 7/23/02 18:35
HHPS182	7/23/2002	15:15	29.5	300		none
HHPS182	7/23/2002	16:30	19.5	200		Northern duckbill was flowing. Sample collected from the northern duckbill.
HHPS182	7/23/2002	17:41	21	1,000		none
HHPS182	7/23/2002	18:52	22	20,000	>	none
HHT1	7/23/2002	15:07	20	100	<	none
HHT1	7/23/2002	16:34	21.4	100	<	none
HHT1	7/23/2002	17:44	21	100	<	none
HHT1	7/23/2002	18:56	21	100	<	Slack tide
HHT2	7/23/2002	14:55	22.5	500		Water depth at gage=21 inches

Station	Date	Time	Water Temp (degC)	Fecal Coliforms (cts/100ml)	FC Qualifier	Field Comments
HHT2	7/23/2002	16:44	23	300		Water depth at gage=15 inches
HHT2	7/23/2002	17:52	22	300		Water depth at gage=15 inches
HHT2	7/23/2002	19:03	22	900		Water depth at gage=15 inches; outgoing tide
HHT4	7/23/2002	14:42	22	100	<	none
HHT4	7/23/2002	16:56	21.5	100	<	none
HHT4	7/23/2002	18:04	21	100	<	none
HHT4	7/23/2002	19:15	21	200		Incoming tide
HHT5	7/23/2002	14:29	21	50		none
HHT5	7/23/2002	17:09	22	100		none
HHT5	7/23/2002	18:11	21	100	<	Incoming tide
HHT5	7/23/2002	19:20	21	300		none
HHT8	7/23/2002	16:17	23	100	<	none
HHT8	7/23/2002	17:40	23	100		none
HHT8	7/23/2002	18:23	22	100	<	none
HHPS015	10/16/2002	10:00	NA	100		
HHPS015	10/16/2002	11:35	NA	1,700		
HHPS015	10/16/2002	13:25	NA	2,200		
HHPS015	10/16/2002	15:05	NA	6,600		
HHPS015	10/16/2002	16:05	NA	3,500		
HHPS015	10/17/2002	12:25	NA	700		steady flow
HHPS016	10/16/2002	10:15	NA	100	<	
HHPS016	10/16/2002	11:43	NA	700		
HHPS016	10/16/2002	13:30	NA	5,300		
HHPS016	10/16/2002	15:20	NA	5,600		
HHPS016	10/16/2002	16:10	NA	8,300		
HHPS016	10/17/2002	12:30	NA	2,000		steady flow
HHPS016DUP	10/16/2002	13:34	NA	4,700		Field duplicate of sample collected at 10/16/02 1330.
HHPS016DUP	10/16/2002	16:15	NA	8,500		Field duplicate of sample collected at 10/16/02 1610.
HHPS055	10/16/2002	10:30	NA	100	<	
HHPS055	10/16/2002	12:30	NA	1,300		
HHPS055	10/16/2002	13:51	NA	2,800		
HHPS055	10/16/2002	15:28	NA	4,400		
HHPS055	10/16/2002	16:32	NA	6,000		
HHPS056	10/16/2002	10:28	NA	100	<	
HHPS056	10/16/2002	12:25	NA	800		

Station	Date	Time	Water Temp (degC)	Fecal Coliforms (cts/100ml)	FC Qualifier	Field Comments
HHPS056	10/16/2002	13:51	NA	1,800		
HHPS056	10/16/2002	15:28	NA	3,500		
HHPS056	10/16/2002	16:32	NA	4,400		
HHPS057	10/16/2002	10:30	NA	50	<	
HHPS061	10/16/2002	10:46	NA	20,000	>	
HHPS061	10/16/2002	12:42	NA	19,400		
HHPS061	10/16/2002	14:05	NA	17,000		
HHPS061	10/16/2002	15:40	NA	5,500		
HHPS061	10/16/2002	16:46	NA	5,900		
HHPS062	10/16/2002	10:47	NA	17,600		
HHPS062	10/16/2002	12:45	NA	4,900		
HHPS062	10/16/2002	14:10	NA	3,100		
HHPS062	10/16/2002	15:40	NA	2,900		
HHPS062	10/16/2002	16:47	NA	1,600		
HHPS063	10/16/2002	10:35	NA	100	<	
HHPS063	10/16/2002	12:39	NA	7,000		
HHPS063	10/16/2002	14:00	NA	8,200		
HHPS063	10/16/2002	15:37	NA	4,900		
HHPS063	10/16/2002	16:43	NA	2,500		
HHPS066	10/16/2002	10:20	NA	300		high tide, some flow out of pipe, sample taken in front
HHPS066	10/16/2002	11:10	NA	1,800		Full pipe width oil sheen flowing out of pipe.
HHPS066	10/16/2002	11:50	NA	11,600		
HHPS066	10/16/2002	13:35	NA	20,000	>	
HHPS066	10/16/2002	14:20	NA	20,000	>	
HHPS066	10/16/2002	15:10	NA	14,100		
HHPS066	10/16/2002	16:05	NA	17,600		
HHPS066	10/16/2002	16:45	NA	7,400		
HHPS067	10/16/2002	12:00	NA	20,000	>	
HHPS067	10/16/2002	13:40	NA	16,200		
HHPS067	10/16/2002	14:15	NA	17,200		
HHPS067	10/16/2002	15:15	NA	11,300		
HHPS067	10/16/2002	16:00	NA	13,700		
HHPS067	10/16/2002	16:50	NA	6,500		
HHPS068	10/16/2002	10:12	NA	600		high tide, standing water, sample taken in front of pipe
HHPS068	10/16/2002	11:00	NA	1,100		

Station	Date	Time	Water Temp (degC)	Fecal Coliforms (cts/100ml)	FC Qualifier	Field Comments
HHPS068	10/16/2002	11:43	NA	1,100		
HHPS068	10/16/2002	13:25	NA	1,300		
HHPS068	10/16/2002	14:05	NA	1,300		
HHPS068	10/16/2002	15:05	NA	5,200		
HHPS068	10/16/2002	15:50	NA	5,600		
HHPS068	10/16/2002	16:35	NA	7,000		
HHPS069	10/16/2002	10:15	NA	1,300		high tide, standing water
HHPS069	10/16/2002	10:50	NA	1,300		
HHPS069	10/16/2002	11:35	NA	1,000		
HHPS069	10/16/2002	13:20	NA	9,300		
HHPS069	10/16/2002	14:00	NA	9,800		
HHPS069	10/16/2002	15:00	NA	13,800		
HHPS069	10/16/2002	15:45	NA	14,800		
HHPS069	10/16/2002	16:30	NA	18,800		
HHPS069DUP	10/16/2002	13:20	NA	9,700		Field duplicate of sample collected at 10/16/02 1320.
HHPS069DUP	10/16/2002	15:00	NA	13,100		Field duplicate of sample collected at 10/16/02 1500.
HHPS069DUP	10/16/2002	16:30	NA	18,200		Field duplicate of sample collected at 10/16/02 1630.
HHPS070	10/16/2002	10:53	NA	100		
HHPS070	10/16/2002	12:52	NA	4,600		
HHPS070	10/16/2002	14:12	NA	7,200		
HHPS070	10/16/2002	15:25	NA	17,000		flow, sample
HHPS070	10/16/2002	16:46	NA	7,000		
HHPS070DUP	10/16/2002	15:26	NA	16,700		flow, sample. Field duplicate of sample collected at 10/16/02 1525.
HHPS071	10/16/2002	10:15	NA	40		sample, variable pulse flow
HHPS071	10/16/2002	11:30	NA	3,100		Flow / sample
HHPS071	10/16/2002	13:00	NA	2,800		flow, sample
HHPS071	10/16/2002	14:30	NA	1,700		sample, flow meas
HHPS071	10/16/2002	16:00	NA	2,200		
HHPS072	10/16/2002	11:35	NA	400		sample ponded, no flow meas
HHPS072	10/16/2002	13:10	NA	1,300		flow,sample
HHPS072	10/16/2002	14:35	NA	5,200		sample, flow meas
HHPS072	10/16/2002	16:05	NA	4,900		
HHPS182	10/16/2002	10:30	NA	2,000	>	sample, no flow out
HHPS182	10/16/2002	11:45	NA	4,400		sample coll. closer to South pipe
HHPS182	10/16/2002	13:15	NA	8,500		both pipe flowing, coll. Btw

Station	Date	Time	Water Temp (degC)	Fecal Coliforms (cts/100ml)	FC Qualifier	Field Comments
HHPS182	10/16/2002	14:41	NA	20,000	>	most flow from N pipe, sample from N pipe
HHPS182	10/16/2002	16:08	NA	8,100		sample from N pipe, both flow
HHPS182DUP	10/16/2002	11:46	NA	3,600		sample coll. closer to South pipe. Field duplicate of sample collected 10/16/02 1145.
HHPS182DUP	10/16/2002	14:42	NA	20,000	>	most flow from N pipe, sample from N pipe. Field duplicate of sample collected at 10/16/02 1441.
HHT1	10/16/2002	9:40	NA	80		Incoming, almost slack high
HHT1	10/16/2002	11:49	NA	60		outgoing tide
HHT1	10/16/2002	13:18	NA	5	<	
HHT1	10/16/2002	14:45	NA	50		
HHT1	10/16/2002	16:10	NA	10		incoming tide
HHT1	10/17/2002	13:00	NA	40		strong outgoing tide
HHT2	10/16/2002	9:48	NA	110		outgoing, barely - 65"
HHT2	10/16/2002	11:57	NA	130		outgoing 35"
HHT2	10/16/2002	13:24	NA	310		19"
HHT2	10/16/2002	14:52	NA	440		16"
HHT2	10/16/2002	16:19	NA	1,070		16", outgoing
HHT2	10/17/2002	13:10	NA	1,960		strong outgoing tide, 26"
HHT4	10/16/2002	10:00	NA	10	<	slack tide
HHT4	10/16/2002	12:09	NA	30		outgoing
HHT4	10/16/2002	13:30	NA	160		
HHT4	10/16/2002	14:59	NA	240		
HHT4	10/16/2002	16:29	NA	100		incoming?
HHT4	10/17/2002	13:25	NA	30		weak outgoing tide
HHT5	10/16/2002	10:05	NA	10	<	outgoing tide
HHT5	10/16/2002	12:13	NA	10	<	outgoing
HHT5	10/16/2002	13:38	NA	20		
HHT5	10/16/2002	15:12	NA	50		outgoing, barely
HHT5	10/16/2002	16:34	NA	30		incoming
HHT5	10/17/2002	13:35	NA	980		strong outgoing tide
HHT8	10/16/2002	10:25	NA	20		
HHT8	10/16/2002	11:48	NA	20		
HHT8	10/16/2002	13:45	NA	20	>	
HHT8	10/16/2002	15:23	NA	300		
HHT8	10/16/2002	16:26	NA	100	<	
HHT8	10/17/2002	12:40	NA	30		outgoing tide

Table D2: Stormwater flow measurements from Hampton Harbor TMDL wet weather sampling program.

Station	Date	Time	Flow Method	Discharge Qualifier	Discharge (cfs)	Depth (in)	Diameter (in)	Velocity (ft/s)	Comments
HHPS070	7/23/2002	15:39	none	no data					No flow measurement recorded. Time taken from lab login sheet.
HHPS071	7/23/2002	15:45	none	=	0				No flow. Time estimated from lab login sheet.
HHPS072	7/23/2002	15:50	none	=	0				No flow. Time estimated from lab login sheet.
HHPS070	7/23/2002	16:10	pipemethod-float	=	0.06	3.25	28	4.73	1 ft rod used
HHPS071	7/23/2002	16:15	pipemethod-meter	=	0.24	4	28	0.65	
HHPS072	7/23/2002	16:20	modUSGS-meter	=	0.26				Field team recorded the flow of both HHPS071 and HHPS072 as being 30 in wide by 2 in deep with velocity 1.21 ft/s. Calculated combined flow using w*d*v (=0.5 cfs). Subtracted flow at HHPS071 (0.24 cfs) to estimate flow from HHPS072.
HHPS070	7/23/2002	17:27	pipemethod-meter	=	0.37	4	28	0.99	depth not recorded; remembered on 7/24/02 by field team to be approximately 4"
HHPS071	7/23/2002	17:30	pipemethod-meter	=	0.14	4.5	28	0.32	time taken from lab login sheet
HHPS072	7/23/2002	17:33	modUSGS-meter	=	0.61	8		0.61	time taken from lab login sheet, box culvert with dimensions 18" x 8". Flow calculated by w*d*v.
HHPS070	7/23/2002	18:25	pipemethod-meter	=	0.11	3.75	28	0.32	time taken from lab login sheet
HHPS070DUP	7/23/2002	18:25	pipemethod-meter	=	0.09	3.75	28	0.27	Field duplicate of HHPS070 7/23/02 18:25; time taken from lab login sheet
HHPS071	7/23/2002	18:30	pipemethod-float	=	0.03	3	28	0.14	time taken from lab login sheet
HHPS071DUP	7/23/2002	18:30	pipemethod-float	=	0.03	3	28	0.135	Field duplicate of HHPS071 7/23/02 18:30;velocity measured with 2 ft rod, time taken from lab login sheet
HHPS072	7/23/2002	18:35	modUSGS-meter	=	0.2	3.5		0.45	box culvert with dimensions of 18" x 3.5"; flow calculated by w*d*v. time taken from lab login sheet
HHPS072DUP	7/23/2002	18:35	modUSGS-meter	=	0.18	3.5		0.42	Field duplicate of HHPS072 7/23/02 18:35. box culvert with dimensions of 18" x 3.5"; flow calculated by w*d*v. time taken from lab login sheet
HHPS055	7/23/2002	14:46	none	no data					small flow, but unreadable due to equipment failure and high winds
HHPS054	7/23/2002	14:51	none		0				no flow. This pipe never flowed during the course of the storm per P. Foss.
HHPS056	7/23/2002	14:56	none	no data					small flow, but unreadable due to equipment failure and high winds. This pipe receives most of its flow from HHPS055.
HHPS057	7/23/2002	14:57	none	=	0				no flow, just a trickle. This pipe never flowed during the course of the storm per P. Foss.
HHPS055	7/23/2002	16:00	none	no data					small flow, but unreadable due to equipment failure and high winds

Station	Date	Time	Flow Method	Discharge Qualifier	Discharge (cfs)	Depth (in)	Diameter (in)	Velocity (ft/s)	Comments
HHPS015	7/23/2002	16:25	none	no data					small flow, but unreadable due to equipment failure and high winds
HHPS016	7/23/2002	16:44	none	no data					flowing but unreadable due to equipment failure/high winds
HHPS055	7/23/2002	17:03	none	no data					small flow, but unreadable due to equipment failure and high winds
HHPS015	7/23/2002	17:46	pipemethod-meter	=	0.32	3.25	42	0.93	
HHPS016	7/23/2002	17:55	pipemethod-meter	=	2.07	6.5	60	1.8	
HHPS055	7/23/2002	18:06	none	no data					low flow, unable to measure
HHPS015	7/23/2002	18:31	pipemethod-meter	=	0.38	3.437	42	1.03	
HHPS016	7/23/2002	18:38	pipemethod-meter	=	4.06	9	60	2.2	
HHPS016DUP	7/23/2002	18:50	pipemethod-meter	=	3.88	9	60	2.1	Field duplicate of HHPS016 7/23/02 18:38
HHPS069	7/23/2002	14:57	none	<	0.02				There was a small current but the wind prevented a flow measurement using the float. Small flow but unmeasureable. Flow value assumed to be less than the lowest recorded flow value (0.02 cfs).
HHPS068	7/23/2002	15:02	none	=	0				Standing water but no flow.
HHPS066	7/23/2002	15:08	none	<	0.02				There was a small current but the wind prevented a flow measurement. Small flow but unmeasureable. Flow assumed to be less than the lowest recorded flow value (0.02 cfs).
HHPS067	7/23/2002	15:18	none	=	0				No flow. Just a trickle.
HHPS069	7/23/2002	16:09	pipemethod-meter	=	0.63	3.375	36	1.88	First flush
HHPS068	7/23/2002	16:19	none	=	0				Standing water but no flow.
HHPS066	7/23/2002	16:20	pipemethod-meter	=	0.52	3.625	36	1.59	First flush
HHPS067	7/23/2002	16:30	none	=	0		12		No flow
HHPS069	7/23/2002	16:35	pipemethod-meter	=	0.55	4.25	36	1.17	Heavy flow with debris
HHPS068	7/23/2002	16:45	none	=	0				Standing water but no flow.
HHPS068DUP	7/23/2002	16:45	none	=	0				Standing water but no flow. Duplicate measurement.
HHPS066	7/23/2002	16:50	pipemethod-meter	=	0.26	2.25	36	1.4	
HHPS067	7/23/2002	17:00	pipemethod-float	=	0.03	0.875	12	1.06	
HHPS069	7/23/2002	17:20	pipemethod-meter	=	1.91	5.5	36	2.8	
HHPS068	7/23/2002	17:33	none	=	0				Standing water but no flow
HHPS066	7/23/2002	17:36	pipemethod-meter	=	0.92	4.25	36	1.96	
HHPS067	7/23/2002	17:45	pipemethod-float	=	0.09	1.75	12	1.22	Much stronger flow than before
HHPS069	7/23/2002	17:50	pipemethod-meter	=	1.34	5.375	36	2.03	
HHPS068	7/23/2002	18:01	modUSGS-float	=	0.82	8		0.32	Box culvert of dimensions 46 in wide, 8 inches deep. Flow calculated by w*d*v
HHPS066	7/23/2002	18:10	pipemethod-meter	=	0.28	2.5	36	1.31	
HHPS067	7/23/2002	18:24	pipemethod-float	=	0.04	1.25	12	0.82	

Station	Date	Time	Flow Method	Discharge Qualifier	Discharge (cfs)	Depth (in)	Diameter (in)	Velocity (ft/s)	Comments
HHPS067DUP	7/23/2002	18:24	pipemethod-float	=	0.05	1.25	12	1.14	Field duplicate of HHPS067 7/23/02 18:24
HHPS069	7/23/2002	18:35	pipemethod-meter	=	0.45	4.5	36	0.89	
HHPS068	7/23/2002	18:42	modUSGS-float	=	0.24	8		0.096	Box culvert of dimensions 45 in wide, 8 inches deep. Flow calculated by w*d*v. Wind affecting float movement. Flow value is approximate.
HHPS066	7/23/2002	18:50	pipemethod-float	=	0.11	1.75	36	0.84	
HHPS067	7/23/2002	18:55	pipemethod-float	=	0.02	0.75	12	0.8	
HHPS071	10/16/2002	10:15	none			15			pressure induced, flow in then out. Standing water, no measurement
HHPS072	10/16/2002	10:23	none		0				no flow, dry
HHPS073	10/16/2002	10:27	none		0				no flow, dry
HHPS071	10/16/2002	11:30	pipemethod-float		0.27	4	28	0.71	
HHPS072	10/16/2002	11:35	none	no data		10.5			ponded water
HHPS073	10/16/2002	11:37	none		0				dry
HHPS071	10/16/2002	13:00	pipemethod-float		0.2	4.5	28	0.4467	
HHPS072	10/16/2002	13:05	modUSGS-meter		0.21	2		1.25	Box culvert with dimensions 12" x 2". Cons. width estimated; bulk of flow 12" wide
HHPS073	10/16/2002	13:10	none		0				dry
HHPS071	10/16/2002	14:30	pipemethod-float		0.88	9	28	0.742	
HHPS072	10/16/2002	14:35	modUSGS-meter		0.65	3.5		1.12	Box culvert of dimensions 24 in wide, 3.5 inches deep. Flow calculated by w*d*v
HHPS073	10/16/2002	14:37	none		0				dry
HHPS070	10/16/2002	15:25	pipemethod-meter		0.16	3.75	28	0.476	
HHPS070DUP	10/16/2002	15:26	pipemethod-meter		0.16	3.75	28	0.483	Field duplicate of measurement at 10/16/02 1525.
HHPS071	10/16/2002	16:00	pipemethod-float		0.21	4.75	28	0.437	
HHPS072	10/16/2002	16:05	modUSGS-meter		0.46	2.5		1.46	Box culvert of dimensions 18 in wide, 2.5 inches deep. Flow calculated by w*d*v
HHPS073	10/16/2002	16:07	none		0				dry
HHPS070	10/16/2002	16:46	pipemethod-meter		0.5	4.25	28	1.22	
HHPS015	10/16/2002	10:00	none			17.5			flow, but too low to measure
HHPS016	10/16/2002	10:15	none			25			flow, but too low to measure
HHPS054	10/16/2002	10:28	none		0				dry
HHPS055	10/16/2002	10:30	none						pipe completely submerged, flow, but culvert completely submerged
HHPS057	10/16/2002	10:30	none						completely submerged, flowing, but not measurable
HHPS061	10/16/2002	10:46	none						flowing but completely submerged, not measurable
HHPS062	10/16/2002	10:47	none						completely submerged, flowing but not measurable
HHPS070	10/16/2002	10:53	none		0	20.1	28		standing water but no flow

Station	Date	Time	Flow Method	Discharge Qualifier	Discharge (cfs)	Depth (in)	Diameter (in)	Velocity (ft/s)	Comments
HHPS015	10/16/2002	12:15	pipemethod-meter		0.24	2.9	42	0.82	Flow taken 40 minutes after sample collected for FC (11:35) because equipment failed and needed to be replaced.
HHPS016	10/16/2002	12:20	pipemethod-meter		0.88	5.8	60	0.903	Flow taken 40 minutes after sample collected for FC (11:43) because equipment failed and needed to be replaced.
HHPS054	10/16/2002	12:30	none		0				dry, time of observation estimated from time of sample collection at HHPS055
HHPS055	10/16/2002	12:30	modUSGS-meter		0.11	2.9		0.18	Box culvert of dimensions 31 in wide, 2.9 inches deep. Flow calculated by w*d*v
HHPS057	10/16/2002	12:30	none		0				dry, time of observation estimated from time of sample collection at HHPS055
HHPS061	10/16/2002	12:42	none		0				No flow, standing water
HHPS062	10/16/2002	12:45	modUSGS-meter	>	0.14			0.68	Box culvert with dimensions 11.5 in wide and N/A in deep. Depth not recorded; assumed to be equal to 2.6 in as was observed at 1410. This is a low estimate so the result has been qualified as "greater than" value.
HHPS070	10/16/2002	12:57	pipemethod-meter		0.33	3.8	28	0.96	
HHPS070DUP	10/16/2002	12:57	pipemethod-meter		0.31	3.8	28	0.8867	Field duplicate of measurement at 10/16/02 1257.
HHPS015	10/16/2002	13:25	pipemethod-meter		0.56	3.9	42	1.24	
HHPS016	10/16/2002	13:30	pipemethod-meter		4.68	10.5	60	2.03	
HHPS016DUP	10/16/2002	13:34	pipemethod-meter		4.96	10.5	60	2.15	Field duplicate of measurement at 10/16/02 1330.
HHPS054	10/16/2002	13:51	none		0				dry, time of observation estimated from time of sample collection at HHPS055
HHPS055	10/16/2002	13:51	none			12			Box culvert with dimensions 30 in wide by 12 in deep. Flow, but too low to measure
HHPS057	10/16/2002	13:51	none		0				dry, time of observation estimated from time of sample collection at HHPS055
HHPS061	10/16/2002	14:05	none			1.1			flow, but too low to measure. Box culvert width 11.5" depth 1.1"
HHPS062	10/16/2002	14:10	none		0	2.6			standing water, no flow. Box culvert 14.8 wide by 2.6" deep
HHPS070	10/16/2002	14:40	pipemethod-meter		0.66	4.5	28	1.49	
HHPS015	10/16/2002	15:05	pipemethod-meter		0.72	4.6	42	1.26	
HHPS016	10/16/2002	15:20	pipemethod-meter		8.52	13.6	60	2.55	
HHPS054	10/16/2002	15:28	none		0				dry, time of observation estimated from time of sample collection at HHPS055
HHPS055	10/16/2002	15:28	modUSGS-meter		0.47	12.4		0.18	Box culvert of dimensions 30 in wide, 12.4 inches deep. Flow calculated by w*d*v

Station	Date	Time	Flow Method	Discharge Qualifier	Discharge (cfs)	Depth (in)	Diameter (in)	Velocity (ft/s)	Comments
HHPS057	10/16/2002	15:28	none		0				dry, time of observation estimated from time of sample collection at HHPS055
HHPS061	10/16/2002	15:40	none			2.8			Box culvert of dimensions 15.5 in wide, 2.8 inches deep. Flow not recorded, could not calculate discharge (assumed to be standing water?)
HHPS062	10/16/2002	15:40	modUSGS-meter		0.07	1.1		0.776	Box culvert of dimensions 11.5 in wide, 1.1 inches deep. Flow calculated by w*d*v
HHPS015	10/16/2002	16:05	pipemethod-meter		0.8	4.4	42	1.49	
HHPS016	10/16/2002	16:10	pipemethod-meter		7.57	12.8	60	2.47	
HHPS016DUP	10/16/2002	16:15	pipemethod-meter		7.6	12.8	60	2.48	Field duplicate of measurement at 10/16/02 1610.
HHPS054	10/16/2002	16:32	none		0				dry, time of observation estimated from time of sample collection at HHPS055
HHPS055	10/16/2002	16:32	modUSGS-meter		0.44	11.8		0.18	Box culvert of dimensions 30 in wide, 11.8 inches deep. Flow calculated by w*d*v
HHPS057	10/16/2002	16:32	none		0				dry, time of observation estimated from time of sample collection at HHPS055
HHPS061	10/16/2002	16:46	none		0	3			Box culvert of dimensions 15 in wide, 3 inches deep. No flow, standing water.
HHPS062	10/16/2002	16:47	modUSGS-meter		0.17	1.8		1.21	Box culvert of dimensions 11.5 in wide, 1.8 inches deep. Flow calculated by w*d*v
HHPS068	10/16/2002	10:12	none						high tide, standing water. Some flow was observed at this pipe (starting at 1030), but measurement was not attempted. Time of observation taken from lab login sheet.
HHPS069	10/16/2002	10:15	none						high tide, standing water. Measurement was not attempted. Time of observation taken from lab login sheet.
HHPS066	10/16/2002	10:20	none						high tide, standing water. Some flow was observed at this pipe, but measurement was not attempted. Time of observation taken from lab login sheet.
HHPS067	10/16/2002	10:20	none						high tide, standing water. Measurement was not attempted. Time of observation taken from lab login sheet.
HHPS069	10/16/2002	10:50	pipemethod-float		2.3	20.4	36	0.557	
HHPS068	10/16/2002	10:56	modUSGS-float		4.25	21		0.655	Box culvert of dimensions 44.5 in wide, 21 inches deep. Flow calculated by w*d*v
HHPS067	10/16/2002	11:10	none		0				dry, just a trickle. Time of observation estimated from time of sample collection at HHPS066
HHPS066	10/16/2002	11:15	pipemethod-float		1.6	15	36	0.573	oily sheen
HHPS069	10/16/2002	11:35	pipemethod-meter		2.03	7.75	36	1.82	lots of debris, strong flow

Station	Date	Time	Flow Method	Discharge Qualifier	Discharge (cfs)	Depth (in)	Diameter (in)	Velocity (ft/s)	Comments
HHPS068	10/16/2002	11:43	modUSGS-meter		1.82	8.667		0.636	Box culvert of dimensions 47.5 in wide, 8.667 inches deep. Flow calculated by w*d*v
HHPS066	10/16/2002	11:48	pipemethod-meter		0.83	4.625	36	1.56	debris and oily sheen
HHPS067	10/16/2002	12:00	pipemethod-float		0.05	1.125	12	1.37	
HHPS068	10/16/2002	13:25	modUSGS-meter		0.49	5.72		0.27	Box culvert of dimensions 46 in wide, 5.72 inches deep. Flow calculated by w*d*v
HHPS069	10/16/2002	13:30	pipemethod-meter		1.7	5.25	36	2.67	oily sheen
HHPS069DUP	10/16/2002	13:30	pipemethod-meter		1.34	5.25	36	2.1	Oily sheen. Field duplicate of measurement at 10/16/02 1330.
HHPS066	10/16/2002	13:35	pipemethod-meter		0.77	4.0625	36	1.76	oily sheen
HHPS067	10/16/2002	13:40	pipemethod-float		0.05	1.25	12	1.24	
HHPS069	10/16/2002	14:00	pipemethod-meter		1.82	5.5	36	2.67	oily sheen
HHPS068	10/16/2002	14:05	modUSGS-meter		0.75	5.575		0.42	Box culvert of dimensions 46.25 in wide, 5.575 inches deep. Flow calculated by w*d*v
HHPS067	10/16/2002	14:15	pipemethod-float		0.06	1.125	12	1.52	
HHPS066	10/16/2002	14:20	pipemethod-meter		0.91	4.125	36	2.02	
HHPS069	10/16/2002	15:00	pipemethod-meter		2.74	6.5	36	3.15	
HHPS068	10/16/2002	15:05	modUSGS-meter		1.61	6.875		0.71	Box culvert of dimensions 47.5 in wide, 6.875 inches deep. Flow calculated by w*d*v
HHPS069DUP	10/16/2002	15:06	pipemethod-meter		2.41	6.5	36	2.77	Field duplicate of measurement at 10/16/02 1500.
HHPS066	10/16/2002	15:10	pipemethod-meter		0.79	4.125	36	1.76	oily sheen
HHPS067	10/16/2002	15:15	pipemethod-float		0.07	1.375	12	1.4	turbid water
HHPS069	10/16/2002	15:45	pipemethod-meter		1.32	5.5	36	1.93	
HHPS068	10/16/2002	15:50	modUSGS-meter		1.29	5.9375		0.67	Box culvert of dimensions 46.75 in wide, 5.93 inches deep. Flow calculated by w*d*v
HHPS067	10/16/2002	16:00	pipemethod-float		0.04	1	12	1.15	
HHPS066	10/16/2002	16:05	pipemethod-meter		0.46	3.25	36	1.46	
HHPS069	10/16/2002	16:30	pipemethod-meter		1.3	5.25	36	2.03	
HHPS068	10/16/2002	16:35	modUSGS-meter		0.87	5.75		0.47	Box culvert of dimensions 46.5 in wide, 5.75 inches deep. Flow calculated by w*d*v
HHPS066	10/16/2002	16:45	pipemethod-meter		0.77	3.75	36	1.97	
HHPS067	10/16/2002	16:50	pipemethod-float		0.06	1.125	12	1.63	

Table D3: Stage height-flow relationship for HHT2

Date: 11/15/2002

Profile #	Time	Measured Flow (cfs)	Stage Ht (in)
Profile #1	10:05	41.80	45.25
Profile #2	10:41	37.06	35.38
Profile #3	11:15	26.09	25.86
Profile #4	12:05	9.81	18.80
Profile #5	12:50	4.51	16.26
Profile #6	13:42	3.36	15.50
Profile #7	14:31	2.15	15.00

Quadratic relationship: $y=-0.0434x^2 + 3.9401x - 47.712$

$y=$ flow (cfs)

$x=$ stage height (in)

Table D4: Flow through pump stations serving HHPS182

7/23/2002

Pipe	Pump station	Running Time Pump 1 (min)	Running Time Pump 2 (min)	Total (min)	Pump Rate (gal/min)	Total Flow (gal)
North Pipe	River Street	38	6	44	3750	165,000
	Ocean Blvd	25	10	35	3750	131,250
	Subtotal	NA	NA	NA	NA	296,250
South Pipe	Subtotal*	NA	NA	NA	NA	118,500
Both Pipes	TOTAL	NA	NA	NA	NA	414,750

10/16/2002

Pipe	Pump station	Running Time Pump 1 (min)	Running Time Pump 2 (min)	Total (min)	Pump Rate (gal/min)	Total Flow (gal)
North Pipe	River Street	38	32	70	3750	262,500
	Ocean Blvd	78	21	99	3750	371,250
	Total					633,750
South Pipe	Subtotal*	NA	NA	NA	NA	253,500
Both Pipes	TOTAL	NA	NA	NA	NA	887,250

* Estimated by mulitplying the total from the north pipe by 0.4, the ratio of the area drained by the south pipe to the area drained by the north pipe.

Table D5: Stormwater loading calculations for 7/23/02 and 10/16/02 sampling events.

Station	Date	Time	Instantaneous Loading Rate (bill org/day)	Interval Loading Rate (bill org/day)	Interval Duration (d)	Total Load (bill org)	Comments
HHPS015	7/23/2002	15:46	6.26	7.05	0.0285	1.7	Assumes flow at 15:46 and 16:27 were the same as the first reading at 17:46. Total load from this pipe will be higher because the flow remained high at the end of the sampling event.
	7/23/2002	16:27	7.83	17.62	0.0549		
	7/23/2002	17:46	27.40	16.96	0.0313		
	7/23/2002	18:31	6.51				
HHPS016	7/23/2002	15:48	10.13	22.79	0.0389	11.1	Assumes flow at 15:48 and 16:44 was the same as the first reading at 1755. Total load from this pipe will be higher because the flow remained high at the end of the sampling event.
	7/23/2002	16:44	35.45	53.18	0.0493		
	7/23/2002	17:55	70.91	254.01	0.0299		
	7/23/2002	18:38	437.10				
HHPS055	7/23/2002					0.0	Assumed to be negligible because there was never any significant flow.
HHPS056	7/23/2002					0.0	Assumed to be neglible because there was never any significant flow. High FC concentrations during the storm suggest a local source since they did not occur at HHPS055.
HHPS066	7/23/2002	15:13	0.05	108.18	0.0465	13.9	
	7/23/2002	16:20	216.30	134.87	0.0208		
	7/23/2002	16:50	53.44	111.14	0.0347		
	7/23/2002	17:40	168.83	86.37	0.0208		
	7/23/2002	18:10	3.91	13.80	0.0278		
	7/23/2002	18:50	23.69				
HHPS067	7/23/2002	15:18	0.00	0.00	0.0500	1.1	Uses flow times for interval. Inserted zero load for two entries at 1518 and 1630 which were recorded as "no flow".
	7/23/2002	16:30	0.00	0.07	0.0208		
	7/23/2002	17:00	0.15	9.54	0.0313		
	7/23/2002	17:45	18.94	19.26	0.0271		
	7/23/2002	18:24	19.57	11.99	0.0215		
	7/23/2002	18:55	4.40				
HHPS068	7/23/2002	15:02	0.00	0.00	0.0472	0.1	Dramatic change in concentrations without a change in flow. May be an underestimate.
	7/23/2002	16:10	0.00	0.00	0.0187		
	7/23/2002	16:37	0.00	0.00	0.0333		
	7/23/2002	17:25	0.00	2.01	0.0243		
	7/23/2002	18:00	4.01	2.89	0.0278		
	7/23/2002	18:40	1.76				

Station	Date	Time	Instantaneous Loading Rate (bill org/day)	Interval Loading Rate (bill org/day)	Interval Duration (d)	Total Load (bill org)	Comments
HHPS069	7/23/2002	15:04	0.05	0.80	0.0451	14.2	
	7/23/2002	16:09	1.54	135.35	0.0188		
	7/23/2002	16:36	269.15	253.75	0.0306		
	7/23/2002	17:20	238.35	135.57	0.0243		
	7/23/2002	17:55	32.79	20.25	0.0278		
	7/23/2002	18:35	7.71				
HHPS070	7/23/2002	15:39	0.15	0.15	0.0215	0.2	Assumes that flow at 15:39 was the same as at 16:10. Loading estimate is an underestimate because it only covers a short duration. Instantaneous load measurement at 1825 deleted because the duplicate FC results had an RPD of 118% which exceeded the data quality objective of 60%.
	7/23/2002	16:10	0.15	4.60	0.0535		
	7/23/2002	17:27	9.05				
	7/23/2002	18:25					
HHPS071	7/23/2002	15:45	0.00	4.40	0.0208	0.6	Uses flow times for interval. Inserted zero load for first entry at 1545 which was recorded as "no flow".
	7/23/2002	16:15	8.81	6.97	0.0521		
	7/23/2002	17:30	5.14	2.86	0.0417		
	7/23/2002	18:30	0.59				
HHPS072	7/23/2002	15:50	0.00	47.08	0.0208	5.2	Uses flow times for interval. Inserted zero load for the first entry at 1550 which was recorded as "no flow".
	7/23/2002	16:20	94.15	65.73	0.0507		
	7/23/2002	17:33	37.31	19.88	0.0431		
	7/23/2002	18:35	2.45				
HHPS182	7/23/2002	15:15				71.8	Based on total estimated discharge during the storm (414,750 gal) and average measured concentration (5,375 cfu/100ml).
	7/23/2002	16:30					
	7/23/2002	17:41					
	7/23/2002	18:52					
HHT2	7/23/2002	14:55	196.60	104.58	0.0757	9.7	
	7/23/2002	16:44	12.55	12.55	0.0472		
	7/23/2002	17:52	12.55	25.10	0.0493		
	7/23/2002	19:03	37.66				
HHPS054	7/23/2002					0.0	No flow
HHPS057	7/23/2002					0.0	No flow
HHPS015	10/16/2002	10:00	0.59	5.29	0.0660	10.8	Assumes flow at 1000 was the same as the flow measured at 1135.
	10/16/2002	11:35	9.98	20.06	0.0764		
	10/16/2002	13:25	30.15	73.21	0.0694		

Station	Date	Time	Instantaneous Loading Rate (bill org/day)	Interval Loading Rate (bill org/day)	Interval Duration (d)	Total Load (bill org)	Comments
	10/16/2002	15:05	116.27	92.39	0.0417		
	10/16/2002	16:05	68.51				
HHPS016	10/16/2002	10:15	2.15	8.61	0.0611	138.4	Assumes flow at 1015 was the same as the flow measured at 1143.
	10/16/2002	11:43	15.07	310.99	0.0743		
	10/16/2002	13:30	606.92	887.18	0.0764		
	10/16/2002	15:20	1167.44	1352.41	0.0347		
	10/16/2002	16:10	1537.38				
HHPS055	10/16/2002	10:30	0.27	1.88	0.0833	5.0	Assumes flow at 1030 and 1351 was the same as the flow measured at 1230.
	10/16/2002	12:30	3.50	5.52	0.0562		
	10/16/2002	13:51	7.54	29.07	0.0674		
	10/16/2002	15:28	50.60	57.60	0.0444		
	10/16/2002	16:32	64.60				
HHPS056	10/16/2002						HHPS056 should be the same as for HHPS055. Use loading estimate for HHPS055. Concentrations are the same for the two sites. These are not unique sources so they should be grouped.
HHPS057	10/16/2002					0.0	This pipe did not flow.
HHPS061	10/16/2002					0.0	This pipe did not flow.
HHPS062	10/16/2002	10:47	60.29	38.54	0.0819	4.1	Assumes flow at 1047 was the same as the flow measured at 1245.
	10/16/2002	12:45	16.79	8.39	0.0590		
	10/16/2002	14:10	0.00	2.48	0.0625		
	10/16/2002	15:40	4.97	5.81	0.0465		
	10/16/2002	16:47	6.66				
HHPS066	10/16/2002	10:20	11.74	41.11	0.0347	67.0	Assumes flow at 1020 was the same as the flow measured at 1110.
	10/16/2002	11:10	70.47	153.03	0.0278		
	10/16/2002	11:50	235.58	306.20	0.0729		
	10/16/2002	13:35	376.81	411.07	0.0313		
	10/16/2002	14:20	445.33	358.94	0.0347		
	10/16/2002	15:10	272.55	235.33	0.0382		
	10/16/2002	16:05	198.10	168.76	0.0278		
	10/16/2002	16:45	139.42				
HHPS067	10/16/2002	10:20	0.00	0.00	0.0000	10.0	Assigned load value of zero for 10:20 and 11:10 because pipe did not start to flow until 1200.
	10/16/2002	11:10	0.00	12.23	0.5000		
	10/16/2002	12:00	24.47	22.14	0.0694		
	10/16/2002	13:40	19.82	22.54	0.0243		

Station	Date	Time	Instantaneous Loading Rate (bill org/day)	Interval Loading Rate (bill org/day)	Interval Duration (d)	Total Load (bill org)	Comments
	10/16/2002	14:15	25.25	22.30	0.0417		
	10/16/2002	15:15	19.35	16.38	0.0313		
	10/16/2002	16:00	13.41	11.48	0.0347		
	10/16/2002	16:50	9.54				
HHPS068	10/16/2002	10:12	62.39	88.39	0.0333	24.0	Assumes flow at 1012 was the same as the flow measured at 1100.
	10/16/2002	11:00	114.39	81.69	0.0299		
	10/16/2002	11:43	48.99	32.29	0.0708		
	10/16/2002	13:25	15.59	19.72	0.0278		
	10/16/2002	14:05	23.86	114.35	0.0417		
	10/16/2002	15:05	204.85	190.81	0.0313		
	10/16/2002	15:50	176.76	162.89	0.0313		
	10/16/2002	16:35	149.01				
HHPS069	10/16/2002	10:15	73.16	73.16	0.0243	98.2	Assumes flow at 1015 was the same as the flow measured at 1050.
	10/16/2002	10:50	73.16	61.42	0.0313		
	10/16/2002	11:35	49.67	218.26	0.0729		
	10/16/2002	13:20	386.85	411.63	0.0278		
	10/16/2002	14:00	436.42	680.81	0.0417		
	10/16/2002	15:00	925.20	701.61	0.0313		
	10/16/2002	15:45	478.02	538.01	0.0313		
	10/16/2002	16:30	598.01				
HHPS070	10/16/2002	10:53	0.00	18.57	0.0826	14.7	
	10/16/2002	12:52	37.14	76.71	0.0556		
	10/16/2002	14:12	116.27	91.41	0.0507		
	10/16/2002	15:25	66.55	76.10	0.0563		
	10/16/2002	16:46	85.64				
HHPS071	10/16/2002	10:15	0.26	10.37	0.0521	4.7	Assumes flow at 1015 was the same as the flow measured at 1130.
	10/16/2002	11:30	20.48	17.09	0.0625		
	10/16/2002	13:00	13.70	25.15	0.0625		
	10/16/2002	14:30	36.60	23.95	0.0625		
	10/16/2002	16:00	11.30				
HHPS072	10/16/2002	10:23	0.00	1.03	0.4826	7.7	Assumes flow at 1135 was the same as the flow measured at 1305 and assigns a load value of zero for 1023 because pipe was reported as "dry".
	10/16/2002	11:35	2.06	4.37	0.0660		
	10/16/2002	13:05	6.68	44.69	0.0590		
	10/16/2002	14:35	82.70	68.93	0.0625		

Station	Date	Time	Instantaneous Loading Rate (bill org/day)	Interval Loading Rate (bill org/day)	Interval Duration (d)	Total Load (bill org)	Comments
	10/16/2002	16:05	55.15				
HHPS182	10/16/2002	10:30				245.7	Based on total estimated discharge during the storm (887,250 gal) and average measured concentration (8,600 cfu/100ml).
	10/16/2002	11:45					
	10/16/2002	13:15					
	10/16/2002	14:41					
	10/16/2002	16:08					
HHT2	10/16/2002	9:48	112.51	115.97	0.0896	25.6	Assumes flow at 0948 is equal to the highest measured flow because the stage was outside the calibration range.
	10/16/2002	11:57	119.44	103.83	0.0604		
	10/16/2002	13:24	88.22	67.36	0.0611		
	10/16/2002	14:52	46.51	79.81	0.0604		
	10/16/2002	16:19	113.10				
HHPS073	10/16/2002					0.0	No flow
HHPS054	10/16/2002					0.0	No flow

APPENDIX C

QA/QC Review – Tidal Bacteria TMDL Program

STATE OF NEW HAMPSHIRE
Inter-Department Communication

DATE December 17, 2002

FROM Phil Trowbridge
Watershed Management Bureau

AT (OFFICE) Water Division,

SUBJECT QA/QC Review: Tidal Bacteria TMDL Program

TO Vince Perelli

This memorandum summarizes the QA activities conducted under the Tidal Bacteria TMDL Program during 2002. Only one project was completed during this time: the Hampton Harbor Bacteria TMDL.

Summary of QA/QC Objectives
The objectives described in the approved QAPP, dated June 28, 2002, were met. These include the proper training of the field technicians, proper handling of water samples, proper collection of field data, the review of data relative to the acceptance criteria documented in the QAPP, and input of the data to appropriate databases. All water sampling was conducted in accordance with the approved QAPP and the associated SOPs. Each field measurement and laboratory result was reviewed by the Project Manager to determine data quality.

Description of Training Activities
The training session consisted of two parts:
- The Program Manager instructed the Field Team Leaders on proper use of the water quality sampling and flow measurement equipment according to the approved SOPs on 6/12/02. This instruction was given in the field at the project site.

Conformance to QAPP Requirements/Descriptions of Deviations
All inconsistencies with the approved QAPP during the 2002 monitoring season are shown in Table 1.

Limitations of the Data
The data were collected from stormdrains during two rainstorm events. Therefore, these data do not represent ambient or typical conditions.

Table 1. QAPP inconsistencies during the 2002 monitoring season.

QAPP Section	Description	QAPP/SOP Inconsistency
A4	Project Task/Organization	The QA officer is not supposed to also participate in the field sampling. However, due to a lack of staff to help with the sampling, the QA Officer participated in both rounds of sampling. ***This non-conformity is not expected to affect the quality of the data.***
A7	Quality Objectives and Criteria - Precision	One set of duplicate stormwater samples from 7/23/02 had an RPD value for fecal coliforms outside the criteria of <60%. These were duplicate samples of HHPS070 taken at 1825. One measurement was 1700 cfu/100ml the duplicate sample was 6600 cfu/100ml. The field teams did not report any nonconformities with SOPs for these samples. ***These two samples were rejected and not used in any calculations. The data was retained in the database but was flagged with comments describing the high RPD between the two duplicates.*** 3 of the 5 field duplicates of fecal coliforms in harbor samples had RPD values of 67%, which is higher than the criteria of <40%. The FC concentrations in the harbor were low (average: 14.5 cfu/100ml) so the absolute difference in concentrations between these samples was small. ***Therefore, this nonconformity is not expected to affect the quality of the data.*** Stormwater flow measurements One set of duplicate measurements of stormwater flow from 7/23/02 had an RPD of 22% and another set of duplicates from 10/16/02 had an RPD of 24%. The criteria RPD for duplicate flow measurements is <20%. ***These nonconformities were considered acceptable and are not expected to affect the quality of the data***.
A7	Quality Objectives and Criteria – Completeness	Overall- QAPP called for 145 samples per storm for 3 storms. Data on two storms for a completeness of 67% was considered acceptable. Two storms were monitored and a total of 265 samples were collected for a completeness of 61%. ***This non-conformity is not expected to affect the quality of the data. It was most important to get data on two different storms which was done. Many of the planned samples could not be collected during the first storm because some target pipes did not flow during the storm. Based on the number of storms monitored, the completeness would be 2 of 3 (67%).***
B1	Sampling Process Design	Three of the targeted pipes (HHPS061, 062, and 073) were not monitored at all during the 7/23/02 storm because one of the field teams was missing. Two of these pipes HHPS061 and 073 were found to not flow during the storm on 10/16/02 so it can be assumed that they did not flow on 7/23/02. HHPS062 was observed to flow during the second storm so measurements from 7/23/02 represent a datagap. In addition, pre-storm samples were not obtained at the following two pipes on 7/23/02 (excluding pipes that were dry during prestorm conditions): HHPS063 (collected by Pipe Team 2 but mislabeled so rejected) HHT8 (not collected by Pipe Team 2 due to lack of time) On 10/16/02, only one round of harbor samples was collected instead of the 3-4 rounds of samples called for in the QAPP. Very high winds made it unsafe for the boat to be deployed in the harbor during the storm after the first round of samples was collected. ***Taken as a whole, these datagaps do not invalidate the study. Excellent***

QAPP Section	Description	QAPP/SOP Inconsistency
		monitoring coverage of all stormwater pipes was achieved during the second storm. Data from this storm provide good information on the relative importance of each pipe. To make up for the missing boat runs during 10/16/02, the boat stations were monitoring on the day following the storm.
B2	Sampling Methods	Temperature measurements were dropped from the SOPs after the first storm event because the data served no useful purpose and slowed down the field teams. This decision was made by the Project Manager after the field sampling audit of the first sampling event and interviews with field teams. ***This non-conformity is not expected to affect the quality of the data.***
B5	Quality Control	For stormwater samples on 10/16/02, 8 duplicates were taken for 117 samples (6% rate). For harbor samples over both storms, 5 duplicate samples were taken for 60 samples (8% rate). The rate of duplicate samples is supposed to be 10%. ***This non-conformity is not expected to affect the quality of the data.***

Documentation of Usable Data Versus Actual Data Collected

The Program Manager reviewed all results from field sampling and laboratory analysis. Comments relative to the field data were written directly on the field data sheets. **Two laboratory data points were flagged as provisional and not used in TMDL calculations,** as field duplicate samples for several parameters indicated significant deviations from the approved RPDs during the sampling day (Table 2). All other data are acceptable. The provisional data will be input to the database, but will not be used for TMDL calculations.

Table 2. Parameters and site IDs for data and RPDs outside the acceptable range given in the QAPP dated June 7, 2002.

Analysis	Date	Parameter	Site ID
Laboratory	7/23/02 1825	Fecal coliforms	HHPS070, HHPS070DUP

APPENDIX D

QA Officer Report

Quality Assurance Officer Report for the Hampton Harbor Bacteria TMDL

Prepared by Peg Foss, TMDL Coordinator, NHDES
January 9, 2003

The purpose of this Quality Assurance Report is to provide detailed information pertaining to the Hampton Harbor Bacteria TMDL project's compliance with the guidelines set forth in the Quality Assurance Project Plan dated June 7, 2002 ("the QAPP"), approved by EPA on June 28, 2002. This study was conducted under the supervision of Greg Comstock, Supervisor, of the Water Quality Planning Section, Watershed Management Bureau, of the New Hampshire Department of Environmental Services ("NHDES"). The Project Manager for the study is Phil Trowbridge, NH Estuaries Project Coastal Scientist, NHDES. Section D of the QAPP outlines the responsibilities of the QA Officer in reference to the review, verification, validation and reconciliation of the data collected for this study.

In 2002, wet weather monitoring was conducted during two storm events in Hampton Harbor. A memorandum dated December 17, 2002 was prepared by the Project Manager ("the memo") contains a review of all of the known non conformities found during the course of the monitoring work. This Quality Assurance report will serve to provide a detailed assessment of the impact of the nonconformities found on the quality of the data collected to determine whether the data quality objectives set forth in the QAPP have been met. Ultimately it is up to the Project Manager to decide whether or not to include data, collected which falls outside the parameters set forth in the QAPP, in any calculations, assumptions, predictions, or conclusions in the final TMDL Report. If any such suspect data is included, the Project Manager is required to clearly identify the suspect data and the resultant uncertainty associated with it's use.

A detailed discussion of each known nonconformity and decision regarding the inclusion or exclusion of data itemized in Table 1 of the memo and the resultant impact to the project is discussed below;

1. Section A4, Project Task Organization: QA Officer participation in field sampling.
Section A8 of the QAPP requires that all "Field Sampling Team Leaders" participate in a mandatory field training session which was held in the field at the project site on June 12, 2002. The QA Officer participated in the training session and was designated a Field Sampling Team Leader. The attendance sheet for the training session with the signatures of all attendees, including the QA Officer's, is included in Appendix C of the TMDL report. Since the QA Officer met the training requirement as outlined in the QAPP this nonconformity is not expected to affect the quality of the data.

2. Section A7, Quality Objectives and Criteria-Precision: Duplicate samples outside the precision criteria.
Table 3 in Section A7 of the QAPP details the precision criteria requirement for each parameter tested or sampled in the study. The Project Manager is responsible for preparation of the final report and has the ultimate decision authority over whether to accept or reject any data that falls outside any of the criteria set forth in the QAPP.
The Project Manager rejected the fecal coliform duplicate samples taken at sample ID HHPS070 on 7/23/02 because the testing results revealed that samples fell outside the acceptable range of precision identified in section A7, Table 3 of the QAPP. Rejection of this data is in compliance with the criteria set forth in the QAPP.

The Project Manager included three of five fecal coliform duplicate samples taken in the Harbor that fell above the acceptable range in precision. This nonconformity is not expected to have a significant impact on the quality of the results/conclusions drawn from the data because the concentration of FC in the three samples was low, hence the absolute difference in concentrations between the samples was small.

The Project Manager included one set of duplicate flow measurements from each sample round that fell just slightly above the acceptable range of precision. Since the samples were just slightly outside the acceptable range, this nonconformity is not expected to have a significant impact on the quality of the results/conclusions drawn from the data.

3. Section A7, Quality Objectives and Criteria-Completeness: Two storm events monitored.

This TMDL study proposed to collected water quality samples during three storm events of greater than 0.25 inches/day of precipitation between June and October. According to Section A7 of the QAPP, "the study will be sufficiently complete if two storms are monitored" and "a data completeness percentage of 67% is needed". In 2002, sampling/monitoring was conducted during two storm events, both resulted in greater than 0.25 inches/day of total precipitation, therefore the project has met the project description and completeness criteria set forth in the QAPP. An added benefit to the data collected for this study is that the two storm events that were monitored were different. The first storm event was a typical summer thunderstorm with heavy wind and rain over a short period, which resulted in relatively small total precipitation. The second storm was a "Nor'easter" which was much longer in duration and resulted in a much higher amount of total precipitation. Gathering information on two different, but typical storm events over the course of this study affords the opportunity to develop a more comprehensive review of the impact of storms on the water quality and Hampton Harbor and the resultant impact to the shellfish resource found there.

4. Section B1, Sampling Process Design: Data gaps.

The lack of pre storm sampling at two storm pipes (all other rounds collected) is not expected to affect the quality of the data collected at those locations for that storm event.

The lack of sample collection during the first storm at one storm water pipe location is not expected to affect the quality of the data. Water quality sampling was done on this pipe during the second storm event and provided sufficient information relative to the significance of the comparative contribution from this location to the water quality in Hampton Harbor.

According to the Department of Public Health Services 1994 report, the effects of a storm event on water quality in Hampton Harbor have been found to persist for three days. Therefore, the collection of water quality samples in the harbor the day after the second storm, to make up for the missing runs the day of the storm (for safety reasons) is not expected to affect the quality of the data or the results/conclusions drawn from the data.

5. Section B2, Sampling Methods: Temperature Measurements dropped from SOP's.

Section C-1, Assessments and Response Actions, and Section B2 of the QAPP, under "Field Corrective Measures" authorize the Project Manager to make decisions and necessary changes during the course of the study to ensure the quality of the sampling. Section A7 of the QAPP states that "Water temperature will also be measured but no regulatory decisions will be made based on this parameter". Since the collection of temperature data was considered secondary/non critical information, and the activity significantly slowed down the sampling teams during the storm events, the decision to drop temperature measurements from the SOP's should have no impact on the quality of the data or the results/conclusions drawn from the data.

6. Section B5, Quality Control: Duplicate criteria.

According to section B5 of the QAPP, the rate set for the collection of duplicate samples of fecal coliform is10%. The boat team, sampling in Hampton Harbor, fell short of the duplicate criteria by 2%. The Project Manager has decided to include the sampling results from the boat team in TMDL calculations. Since this is a minor deviation from the criteria set forth in the QAPP, the decision to include the data should have no impact on the quality of the data collected or the results/conclusions drawn from the data.

APPENDIX E

Responses to EPA Comments on the Hampton/Seabrook Harbor Bacteria TMDL

September 25, 2003

Introduction

The Hampton/Seabrook Harbor TMDL was made available for public comment between June 1 and August 1, 2003. DES did not receive any public comments on the report. DES added information about the public comment period and then sent a final draft of the report to EPA for approval on August 7, 2003. On September 11, 2003 EPA provided a list of comments on the final report. DES responses to these comments are provided below.

EPA Main Comment: "While NH DES did a good job in the TMDL report (dated August 2003) presenting data and the analysis used for estimating loading reductions needed in the central harbor, we have determined that the report does not provide sufficient information for approving TMDLs for the other AUs listed in the TMDL report. For the tributary areas (eight AUs), there is not enough information on sources, existing loads, and load allocations to ensure that the tributaries will attain water quality standards (WQS). We also do not have sufficient information for the shoreline areas (one AU) to ensure that those areas will meet WQS. However, we encourage NH DES to pursue completion of the bacteria TMDLs for the tributary areas, and would be happy to provide assistance."

Hampton/Seabrook Harbor consists of 14 assessment units (AUs) for 305(b) reporting. Ten of the 14 AUs are listed on New Hampshire's 2002 303(d) list for impairments of the shellfishing designated use. The other four AUs in the harbor are safety zones which are closed for shellfishing due to administrative reasons and therefore are not listed on the 303(d) list.

A revised Figure 1 (shown at the end of this addendum) shows how the ambient harbor stations used to calculate the TMDL relate to the ten AUs on the 303(d) list. The stations surround the two AUs that are conditionally approved for shellfishing in the central harbor area (NHEST600031004-09-01, NHEST600031004-04-03). Therefore, this TMDL should at least apply to both of these AUs.

DES accepts that the TMDL should not apply to the six AUs representing tributaries because there is not enough information in these areas to classify them for shellfishing designations. The tributary AUs are: NHEST600031003-01, NHEST600031004-05, NHEST600031004-06, NHEST600031004-07, NHEST600031004-08-01, and NHEST600031004-08-02.

The remaining two AUs are shoreland areas along the developed portions of Hampton and Seabrook (NHEST600031004-09-02, NHEST600031004-04-02). Both of these AUs are classified as restricted for shellfishing because of the presence of marinas and other potential pollution sources. DES accepts that there is not sufficient information to characterize all the microenvironments along the shoreland areas.

Finally, while DES accepts that the scope of this TMDL should be limited to the two central harbor AUs, we do not agree that separate TMDLs are needed for each of the other eight assessment units. The data collected for the TMDL provides sufficient information to move forward on the implementation plan without any further effort to estimate or allocate bacteria loads. Sources to the shoreline areas and tributaries will be targeted for removal in order to reduce the total loading to the central harbor. We expect that the shoreline areas and tributaries will experience dramatic improvements in water quality as a result of these efforts. The most cost effective next step for these AUs is follow-up monitoring in accordance with the NSSP protocols to determine whether these AUs are still impaired after the implementation plan has been completed.

EPA Comment 1: "Include June-August data in your calculations and, if necessary, revise any tables, including those that present the TMDL (in terms of loading or percent reduction) consistent with the calculation results. These tables, if different from those in the TMDL report, will become part the final TMDL for EPA approval."

The DES Shellfish Program database was queried for FC results collected in June, July, and August between 1993 and 2002. The query returned 257 records, 246 of which were routine (i.e., pre-scheduled) samples. The TMDL calculations were re-run using the updated database. The values in Tables 7, 8, 18, 20, 21, and 22 were updated. Revised versions of these tables are shown at the end of this addendum. As a result of these changes, the percent reduction needed to reach the TMDL from Table 21 changed from 47% to 48%. Therefore, the inclusion of the summer data had a negligible effect on the outcome of the TMDL.

EPA Comment 2: "Present the TMDL load and wasteload allocations as daily loads rather than annual loads."

On the revised Table 21, the annual loads have been divided by 365 days/year to express them as daily loads, rather than annual loads.

EPA Comment 3: "Clarify that although the TMDL is referred to as a 'dry-weather TMDL', the allocations actually apply at all times and weather conditions."

EPA commented that it was unclear whether the TMDL was applicable to all conditions or just the dry weather. The confusion arises because the total load to the harbor during dry weather was used as the TMDL, because the water quality standards are only met during dry weather. However, section 5(b)(i) of the report explicitly states that the TMDL set in the report should result in attainment of the water quality standards during critical conditions. Attainment of the standards during the critical conditions will ensure attainment of the standards for all conditions. Therefore, for the record, the TMDL set for Hampton/Seabrook Harbor is applicable to all times and weather conditions.

EPA Comment 4: "In addition to the 10 NSSP stations, please assign percent reductions at the mouths of the seven tributaries that enter Hampton/Seabrook Harbor. This is important because it gives an indication of loading reductions needed from these sources."

Since this TMDL will only be approved for the two central harbor assessment units, the ten NSSP stations around the central harbor already monitor the points where the tributaries discharge to this area (see revised Figure 1). The mouth of the Blackwater River is monitored at HH2B. Mill Creek and Hunts Island Creek/Browns River are monitored by HH19 and HH12, respectively. Finally, HH5B, HH5C, and HH10 are located in the mouth of the Hampton River. Given the scope of this TMDL, the percent reductions at the mouths of the tributaries have already been calculated and discussed in Table 22 of the report.

EPA Comment 5: "Please explicitly note that illicit connections and minor NPDES permittees are part of the wasteload allocation (WLA) portion of the TMDL, assign allocations to each of these source categories, and revise report tables as necessary. Illicit connections are point sources subject to NPDES permits and should have a WLA set at zero because these discharges are illegal and should be eliminated. For the minor NPDES permittees, please give the current and permitted discharge levels for bacteria. WLAs are needed for these facilities so that it is clear that they are allowed to continue to discharge."

Illicit connections are considered part of the WLA portion of the TMDL because these connections discharge to MS4 stormwater systems. It is not possible to estimate the loading from illicit connections to Hampton Harbor. DES recognizes that these sources are illegal and therefore should have an allocation of zero. Footnote 6 in Table 21 has been changed to reflect this fact.

There are two minor NPDES permittees that discharge to Hampton/Seabrook Harbor in addition to the major discharge of the Hampton WWTF. The combined discharge from these two facilities represents 0.0002% of the annual load of bacteria to the harbor. Allocations for the maximum permitted discharge limits for these two facilities have been added to footnote 6 on Table 21.

EPA Comment 6: "Boats and failing septic systems are properly included in the load allocation (LA) portion of the TMDL, but, if feasible, these should be given separate aggregate LA's. For example, the allocation assigned to boats could reflect the load reduction expected from NH DES's goal of designating the New Hampshire coast as a 'no discharge area'. For failing septic systems, the allocation could be set at zero (if the intent is to eliminate such systems) or at a level that reflects properly operating septic systems (if the expectation is that the systems would be repaired or relocated). If the data or techniques do not exist for estimating or predicting load allocations for these categories, then they may remain part of the gross aggregate load allocation. But because of potential localized impacts, we believe that a separate allocation for boats could be particularly beneficial."

DES is in the process of establishing a No Discharge Area (NDA) for the NH coast. We expect that this designation plus our ongoing work with the DES pumpout boat will reduce the bacteria load from boats; however, we do not feel it is prudent to speculate on the amount of the reduction at this time. There is little information nationally on the effectiveness of a NDA designation on reducing overboard discharges. Estimates of compliance with the law range from 20% to 50% of boaters.(Walz, 2003). Therefore, we do not believe it is feasible to set separate aggregate load allocations for boat discharges and failing septic systems as part of this TMDL.

References Cited

Walz L (2003) Boatings dirty secret, Boating Industry, September/October 2003, pp. 40-49.

REVISED Table 7: Characterization of FC Concentrations in Hampton/Seabrook Harbor

Station	Weighted Geomean	90th %ile (based on systematic random data)
	(mpn/100ml)	(mpn/100ml)
HH10	14	60
HH11	12	61
HH12	14	81
HH17	14	89
HH18	11	55
HH19	19	123
HH1A	16	87
HH2B	15	88
HH5B	16	77
HH5C	17	58
Average	**15**	**78**
NSSP Standard	**14**	**43**

Data Source: DES Shellfish Program, records from 1993-2002

REVISED Table 8: Yearly and autumn dry weather FC concentrations

Period	Sample Size	Geomean (MPN/100ml)	90^{th} %ile (MPN/100ml)
September through May	437	5.56	24.05
September and October	97	16.87	80.77
November through May	340	4.05	12.80
June, July, and August	83	12.73	66.73

Data Source: DES Shellfish Program, 1993-2002, low tide, routine samples

NEW Table: Seasonal FC concentrations for all weather conditions combined.

Period	Sample Size	Geomean (MPN/100ml)	90^{th} %ile (MPN/100ml)
September and October	289	29.26	147.26
November through May	688	6.08	31.62
June, July, and August	246	18.76	138.01

Data Source: DES Shellfish Program, 1993-2002, low tide, routine samples

REVISED Table 18: Modeled FC loads to Hampton/Seabrook Harbor during wet weather

Storm Size	Number of samples	Geomean (MPN/100ml)	Kstorm (bill org/day)
Dry (<0.01 in.)	745	7.50	0
0.02 to 0.50 in.	670	13.52	1,621
0.51 to 1.00 in.	327	18.92	3,074
>1.00 in.	186	36.31	7,758

Data Source: DES Shellfish Program, 1993-2002, all low tide data

REVISED Table 20: Summary of bacteria loads to Hampton/Seabrook Harbor

A. Summary of daily bacteria loads to Hampton/Seabrook Harbor under different rainfall conditions

Source	Bacteria Type	Rainfall Dry (<0.01 in.)	Rainfall 0.02 to 0.50 in.	Rainfall 0.51 to 1.00 in.	Rainfall >1.00 in.	Comments
Hampton WWTF	Human	0.30	0.30	0.30	0.30	From DMRs
	Wildlife	0	0	0	0	
Boat Discharges	Human	238	238	238	238	Estimated
	Wildlife	0	0	0	0	
Dry Weather Non-Point Sources	Human	1,070	1,070	1,070	1,070	Modeled
	Wildlife	713	713	713	713	Modeled
Stormwater Load	Human	0	972	1,844	4,655	Modeled
	Wildlife	0	648	1,229	3,103	Modeled
Total	Human	1,308	2,280	3,152	5,963	
	Wildlife	713	1,361	1,942	3,816	
	Total	**2,021**	**3,642**	**5,095**	**9,779**	

Bacteria load units are billion organisms per day

B. Summary of fecal coliform concentrations in Hampton/Seabrook Harbor under different rainfall conditions

Statistic	Rainfall Dry (<0.01 in.)	Rainfall 0.02 to 0.50 in.	Rainfall 0.51 to 1.00 in.	Rainfall >1.00 in.
Geometric mean concentration	7.50	13.52	18.92	36.31
90th percentile concentration	38.52	88.23	137.75	298.05
Percent of the year with this rainfall amount	55.3%	24.2%	10.9%	9.7%
Days per year with this rainfall amount	202	88	40	35

Fecal coliform concentrations in units of MPN/100ml.

C. Annual bacteria load to Hampton/Seabrook Harbor from different sources

Source	Rainfall Dry (<0.01 in.)	Rainfall 0.02 to 0.50 in.	Rainfall 0.51 to 1.00 in.	Rainfall >1.00 in.	**Total for the year**
Hampton WWTF	61	26	12	11	**110**
Boat Discharges	48,039	21,023	9,469	8,426	**86,957**
Dry Weather Non-Point Sources	359,825	157,464	70,924	63,116	**651,330**
Stormwater Load	0	143,162	122,280	274,677	**540,119**
Total	407,925	321,675	202,685	346,230	**1,278,515**

Bacteria load units are billion organisms per year

Annual load estimated by multiplying the daily load for different rainfalls by the number of days/yr when this condition occurs.

REVISED Table 21: TMDL Calculation

Bacteria TMDL Calculation for Hampton/Seabrook Harbor

		Existing Loads			TMDL Calculation				Percent Reduction Needed[8]
Location	**Source**	Point Sources[2]	Non-Point Sources[3]	Total Load	TMDL[4]	MOS[5]	WLA[6]	LA[7]	
Hampton Harbor	Hampton WWTF	0.3		3,503	2,021	202	80	1,738	48%
	Boat Discharges		238						
	Dry Weather Non-Point Sources		1,784						
	Stormwater Load	148	1,332						
	Total	148.3	3,355						

Notes

1. Bacteria loads expressed as billion organisms per day.

2. Ten percent of the annual stormwater load from Table 20 (Section C) was considered "point sources" (540,119 bill org/yr * 1 yr/365 d * 0.1=148 bill org/day) because the 16 Phase II MS4 pipes accounted for 10% of estimated stormwater load on 7/23/02 and 10/16/02. The average daily WWTF load (0.3) was taken from Table 20 (Section A).

3. Annual loads from boat discharges and dry-weather non-point sources taken from Table 20 (Section A). Average non-point source stormwater load calculated using the annual stormwater load from Table 20, Section C and the point source stormwater load (540,119 bill org/yr * 1 yr/365 d -148 bill org/day = 1332 bill org/day).

4. TMDL set at average daily load for dry weather conditions in Table 20, Section A (2021 bill org/day).

5. MOS set at 10% of the TMDL.

6. WLA set equal to TMDL-MOS multiplied by the ratio of total loads from point sources to total loads from non-point sources ((148.3/3355)*(2021-202)=80 bill org/day). Within the WLA of 80 bill org/day, 7.731 bill org/day is allocated to the three existing NPDES permits discharging to the harbor: The Hampton WWTF which has a maximum permitted load of 7.7 bill org/day, Aquatic Research Organisms, Inc. which has a maximum daily permitted load of 0.024 bill org/day, and EnviroSystems, Inc. which has a maximum daily permitted load of 0.007 bill org/day. The remaining 72.269 bill org/day is allocated to MS4 stormwater discharges. However, any illicit connections discharging to the harbor through MS4 systems will have an allocation of zero because these discharges are illegal. This method of apportioning allocations is from EPA (2001b).

7. LA set equal to TMDL-MOS-WLA.

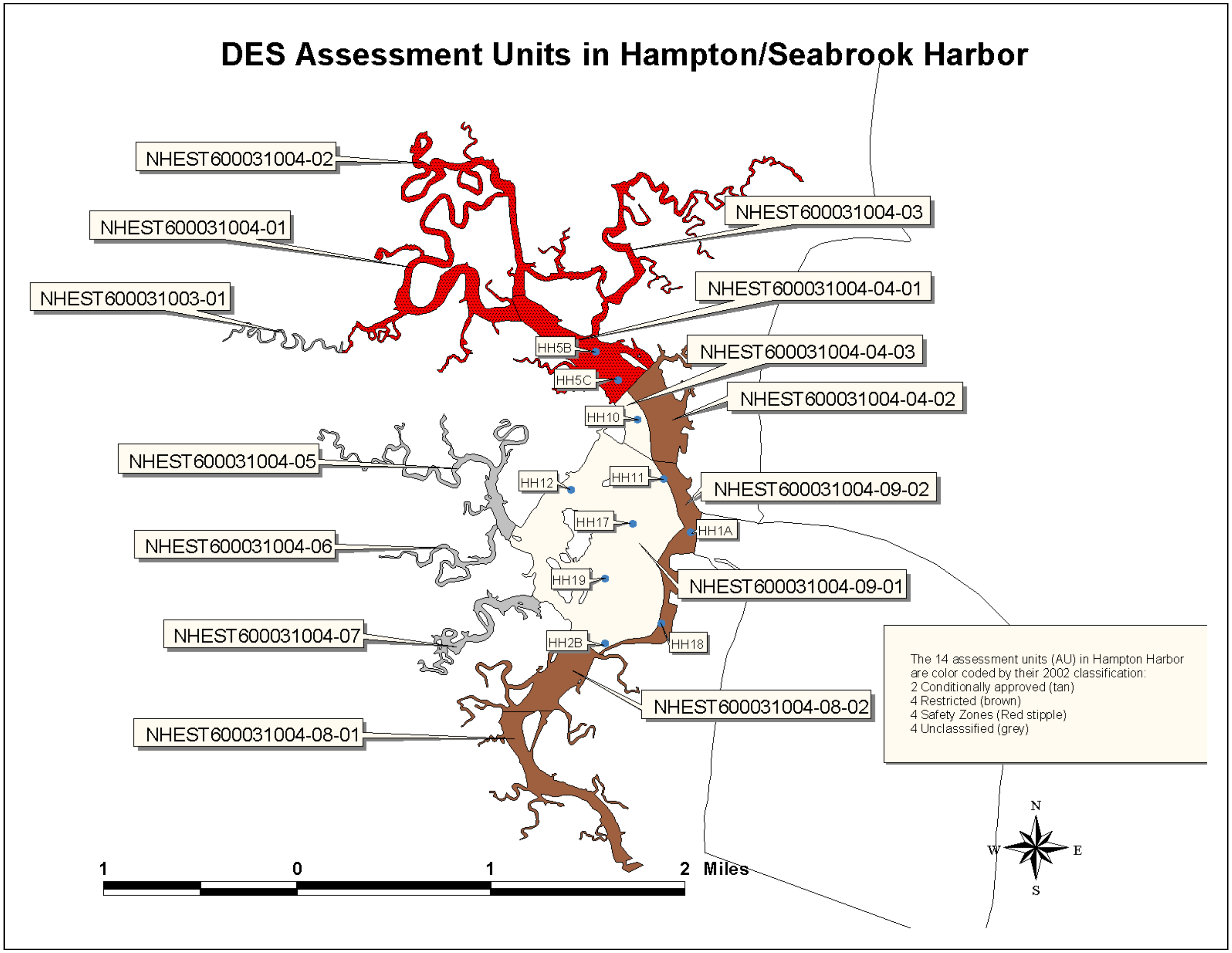
8. Percent reduction calculated by 1-(WLA+LA)/Total Load.

REVISED Table 22: Percent reduction in concentrations needed to achieve the TMDL

Station	90th %ile (based on systematic random data)	Target: TMDL minus MOS	Percent Reduction Needed
	(mpn/100ml)	(mpn/100ml)	(%)
HH10	60	38.7	36%
HH11	61	38.7	37%
HH12	81	38.7	52%
HH17	89	38.7	56%
HH18	55	38.7	30%
HH19	123	38.7	69%
HH1A	87	38.7	55%
HH2B	88	38.7	56%
HH5B	77	38.7	50%
HH5C	58	38.7	33%
Average	**78**	**----**	**47%**
Min	55	----	30%
Max	123	----	69%

Data source: DES Shellfish Program data, 1993-2002, for all months ***including*** June-July-August, low tide samples (collected 3 hours before to 0.5 hours after dead low tide). Only routine samples collected with a systematic random design were used for the 90^{th} %ile calculation.

REVISED Figure 1: DES assessment units in Hampton/Seabrook Harbor



EPA NEW ENGLAND'S TMDL REVIEW

TMDL: Hampton/Seabrook Harbor, New Hampshire

STATUS: Final

IMPAIRMENT/POLLUTANT: Two assessment units (**NHEST600031004-09-01, NHEST600031004-04-03)** for fecal coliform bacteria

REVIEWER: Alison Simcox, PhD (617-918-1684) E-mail: simcox.alison@epa.gov

BACKGROUND: The New Hampshire Department of Environmental Services (NHDES) submitted to EPA New England a final Total Maximum Daily Load (TMDL) report for Hampton/Seabook Harbor, which consists of a main report (dated August 7, 2003) and supplementary information (Appendix E: Responses to EPA Comments on the Hampton/Seabrook Harbor Bacteria TMDL, dated September 25, 2003). This report gives the maximum allowable bacteria loadings for the harbor that will result in attainment of state water quality standards (WQSs). **The following is a summary of EPA's review, which determined that the submission meets statutory and regulatory requirements of TMDLs in accordance with Section 303(d) and 40 CFR Part 130.**

REVIEW ELEMENTS OF TMDLs

Section 303(d) of the Clean Water Act (CWA) and EPA's implementing regulations at 40 C.F.R. § 130 describe the statutory and regulatory requirements for approvable TMDLs. The following information is generally necessary for EPA to determine if a submitted TMDL fulfills the legal requirements for approval under Section 303(d) and EPA regulations, and should be included in the submittal package. Use of the verb "must" below denotes information that is required to be submitted because it relates to elements of the TMDL required by the CWA and by regulation.

1. Description of Waterbody, Pollutant of Concern, Pollutant Sources and Priority Ranking

The TMDL analytical document must identify the waterbody as it appears on the State/Tribe's 303(d) list, the pollutant of concern and the priority ranking of the waterbody. The TMDL submittal must include a description of the point and nonpoint sources of the pollutant of concern, including the magnitude and location of the sources. Where it is possible to separate natural background from nonpoint sources, a description of the natural background must be provided, including the magnitude and location of the source(s). Such information is necessary for EPA's review of the load and wasteload allocations which are required by regulation. The TMDL submittal should also contain a description of any important assumptions made in developing the TMDL, such as: (1) the assumed distribution of land use in the watershed; (2) population characteristics, wildlife resources, and other relevant information affecting the characterization of the pollutant of concern and its allocation to sources; (3) present and future *growth trends, if taken into consideration in preparing the TMDL; and, (4) explanation and analytical basis for expressing the TMDL through surrogate measures, if applicable. Surrogate measures are parameters such as percent fines and turbidity for sediment impairments, or chlorophyl a and phosphorus loadings for excess algae.*

Hampton/Seabrook Harbor, located in the towns of Hampton, Seabrook, and Hampton Falls, is a receiving waterbody for the coastal drainage watershed of New Hampshire. The harbor is surrounded on three sides by salt marshes and on the fourth (eastern edge) by a narrow spit of land. Hydrodynamically, the harbor is characterized by strong tidal flushing (about 88 percent of harbor water on each tide), with tidal exchange occurring through a small gap in the spit on the eastern side.

Soft shell clams (Mya arenaria) are recreationally harvested from three clam flats in the middle of the harbor as well as from smaller flats in the harbor. Classification of growing areas in the harbor was established in accordance with National Shellfish Sanitation Program (NSSP) guidelines and standards. Central harbor areas are "Conditionally approved" for shellfishing, and are open during dry weather, but closed after a rainfall of 0.25 inches from November through May. Currently, all flats are closed by the NH Fish and Game Department in June, July, and August for resource conservation, and in September and October because of frequently elevated bacteria concentrations during these months due to low rainfall and contamination by boat sewage.

The TMDL study was conducted in order to reduce bacteria levels in Hampton/Salem Harbor. The study area included **fourteen assessment units** (AUs) comprising the central harbor area and eight rivers and creeks which are tributaries to the harbor. Ten of the AUs are on the state's § 303(d) list as impaired or as probably impaired by fecal coliform (FC) bacteria for shellfishing. Two of these 10 AUs are also listed as impaired for primary contact recreation, although this listing is based on reports of sewage discharges and not measured violations of enterococci (bacteria indicator for swimming in tidal waters). A report addendum (Appendix E: Responses to EPA Comments on the Hampton/Seabrook Harbor Bacteria TMDL, dated September 25, 2003) clarifies that the TMDL **addresses two of the AU's which comprise the central harbor area (NHEST600031004-09-01 and NHEST600031004-04-03).**

All harbor AUs are also listed on NH's § 303(d) list as impaired for fish consumption and shellfishing because of state-wide advisories by NH Department of Health and Human Services for PCB, dioxin, and Hg contamination. The TMDL report reviewed herein, however, only addresses contamination by bacteria.

NHDES identified the following significant National Pollution Discharge Elimination System (NPDES) point sources of bacteria to the harbor: the Hampton wastewater treatment facility (WWTF) and discrete stormwater discharges from municipal separate storm sewer systems (MS4) subject to EPA Phase II Stormwater regulations. The discrete stormwater discharges identified by NHDES include over 100 pipes, streams, creeks, and conveyances around the harbor. For this TMDL, NHDES monitored 16 MS4 stormwater

sources to the harbor during two storms (see TMDL Review Element #3). NHDES identified two other minor NPDES permitted sources to the harbor: EnviroSystems, Inc. and Aquatic Research Organisms, Inc.

Other significant sources of bacteria to the harbor identified by NHDES include dry-weather human sources (e.g., illicit connections and failing septic systems), dry-weather wildlife/natural sources (birds, other wild animals), and stormwater not conveyed through MS4 system (stormwater conveyed via tributaries and overland runoff).

NHDES used microbial source tracking (ribotyping) to distinguish natural from human sources of bacteria in stormwater. This type of study is important for identifying sources that can be controlled and for defining effective control technologies.

For ribotyping analyses, samples were collected from 10 stations at least every 2 weeks from September 2000 through October 2001. Sixty percent of the E. coli isolates in the samples matched ribotypes strains in the source-species database at the University of New Hampshire. Of these, 15 percent were from wildlife sources, 7 percent were from avian (bird) sources, 26 percent were from human sources, 4 percent were from pets, 8 percent were from livestock. These proportions did not vary significantly for wet and dry weather conditions (Table 9 of TMDL report). NHDES concluded from this study that the ratio of human to wild-animal sources of bacteria to the harbor is about 60:40.

In addition, five samples were collected hourly from each of the 2 storm drains during a rainstorm on October 16, 2002. The largest source of bacteria at both pipes was birds, followed by humans and wildlife (Table 10 in TMDL report), with human sources (human, pet, livestock) accounting for 17 and 35 percent of the matched isolates in each pipe, respectively.

NHDES based its calculations of pollutant loadings and the relative contributions from each source category on monitoring data, including data collected specifically for this TMDL study, and on several simple models, including two mass-balance models (see TMDL Review Element #3).

The TMDL submittal contains a description of important assumptions made in developing the TMDL. These include **an assumption that the two monitored storms (July and October 2002) can reasonably be expected to represent the range of typical storm loadings**. **NHDES also assumed that bacteria loading from each of seven tributaries was roughly the same as the loading from one monitored tributary, Mill Creek.** Modeling assumptions included the following: **(1) dry-weather bacteria sources** included only **the WWTF, boats, and human and wildlife/natural sources, (2) tidal flushing is main mechanism for removing bacteria from harbor, (3) FC concentrations are relatively constant during dry weather, (4) FC bacteria is added to harbor at a rate about equal to its removal by tidal flushing (i.e.,** steady-state conditions).

Assessment: **EPA New England concludes that the TMDL document adequately characterizes Hampton/Seabrook Harbor, the pollutant of concern, and pollutant sources. NHDES used the best available information, including monitoring data collected specifically for this TMDL. EPA New England agrees that the analytical approach, which relies primarily on monitoring data, is adequate, and that the** TMDL includes an adequate description of important assumptions.

2. Description of the Applicable Water Quality Standards and Numeric Water Quality Target

The TMDL submittal must include a description of the applicable State/Tribe water quality standard, including the designated use(s) of the waterbody, the applicable numeric or narrative water quality criterion, and the antidegradation policy. Such information is necessary for EPA's review of the load and wasteload allocations which are required by regulation. A numeric water quality target for the TMDL (a quantitative value used to measure whether or not the applicable water quality standard is attained) must be identified. If the TMDL is based on a target other than a numeric water quality criterion, then a numeric expression, usually site specific, must be developed from a narrative criterion and a description of the process used to derive the target must be included in the submittal.

Tidal waters such as in Hampton/Seabrook Harbor are classified in New Hampshire as Class B waterbodies. WQSs consist of three components: designated uses, criteria, and antidegradation requirements. Three designated uses for tidal waters are relevant to bacteria pollution: shellfishing, primary contact recreation (i.e., swimming), and secondary contact recreation (e.g., boating).

WQSs for shellfishing waters are the NSSP standards, which specify a geometric mean for fecal coliforms of less than 14 MPN/100 ml (MPN is "most probable number") and a 90th percentile of less than 43 MPN/100 ml. In addition, NHDES periodically conducts sanitary surveys for these waters in accord with NSSP guidelines.

For primary contact recreation, tidal waters can contain no more than either the geometric mean of 35 enterococci bacteria per 100 ml (based on at least three samples over a 60-day period) or greater than 104 enterococci per 100 ml in any one sample, unless naturally occurring. There are no WQSs for secondary contact recreation. However, for 303(d) listing, NHDES uses a threshold of enterococci concentrations greater than five times the primary contact recreation standards.

NH's goal for this TMDL study is to meet all WQSs for all designated uses affected by bacteria contamination, using the most stringent WQSs (shellfishing WQSs) as the TMDL target.

Assessment: **EPA New England concludes that NHDES has adequately described New Hampshire's WQSs for bacteria** as well as a numeric water-quality target for the TMDLs

3. Loading Capacity - Linking Water Quality and Pollutant Sources

As described in EPA guidance, a TMDL identifies the loading capacity of a waterbody for a particular pollutant. EPA regulations define loading capacity as the greatest amount of loading that a water can receive without violating water quality standards (40 C.F.R. § 130.2(f)). The loadings are required to be expressed as either mass-per-time, toxicity or other appropriate measure (40 C.F.R. § 130.2(i)). The TMDL submittal must identify the waterbody's loading capacity for the applicable pollutant and describe the rationale for the method used to establish the cause-and-effect relationship between the numeric target and the identified pollutant sources. In most instances, this method will be a water quality model. Supporting documentation for the TMDL analysis must also be contained in the submittal, including the basis for assumptions, strengths and weaknesses in the analytical process, results from water quality modeling, etc. Such information is necessary for EPA's review of the load and wasteload allocations which are required by regulation.

In many circumstances, a critical condition must be described and related to physical conditions in the waterbody as part of the analysis of loading capacity (40 C.F.R. § 130.7(c)(1)). The critical condition can be thought of as the "worst case" scenario of environmental conditions in the waterbody in which the loading expressed in the TMDL for the pollutant of concern will continue to meet water quality standards. Critical conditions are the combination of environmental factors (e.g., flow, temperature, etc.) that results in attaining and maintaining the water quality criterion and has an acceptably low frequency of occurrence. Critical conditions are important because they describe the factors that combine to cause a violation of water quality standards and will help in identifying the actions that may have to be undertaken to meet water quality standards.

NHDES used historical and recent monitoring data, supplemented with microbial source-tracking studies and modeling, to identify sources of bacteria to Hampton/Seabrook Harbor and to estimate relative contributions from different source categories. Field data included low-tide data (FC and enterococci concentrations) for the period 1993-2002 collected at ten NSSP stations used by the NHDES shellfish monitoring program (see map of stations in Appendix A, Figure 5 in TMDL report). This database includes data for the months of June, July, and August when flats are closed. To obtain additional information on stormwater sources of bacteria for this TMDL, NHDES monitored 16 storm drains and seven tributaries during storms in July and October 2002.

Water quality relative to shellfishing standards

To characterize current conditions, NHDES calculated both parts of the NSSP shellfishing standard (the geometric mean and the 90th percentile concentration) for each of the 10 NSSP stations (Table 7 in the TMDL report) using year-round samples taken from 1993-2002. For the geometric mean FC concentration, NHDES used both routine and wet-weather samples to calculate a weighted geometric mean FC concentration for various-sized storms. (Weighting factors were used to account for the frequency of days that each

storm of a specified size occurred.) As noted by NHDES, elevated concentrations of bacteria typically persist in the harbor for three days due to continued loading from the watershed. This was taken into account by multiplying the number of storm events of each size category by three. The NHDES storm analysis showed that geomean FC concentration increased steadily with increasing amounts of rainfall, with the geomean standard (but not the 90th percentile standard) generally expected to be met everywhere in the central harbor following storms under 0.50 in. (Figure 5 in TMDL report).

To estimate the 90th percentile FC concentration, NHDES used an equation recommended by NSSP (p. 15 of TMDL report). Because this method uses only randomly collected data, different storm sizes were not evaluated.

Over the 10-year reporting period, the geometric mean concentrations of all stations but one were close to the WQS of 14 MPN/100 ml. The only station exceeding the geomean standard is at the mouth of Mill Creek. However, for the 90th percentile concentrations, all stations exceeded the WQS of 43 MPN/100 ml (some only slightly). The high variability of FC within the reporting period is attributed to wet-weather runoff and, possibly, boat discharges. While wet-weather loads are important, dry-weather violations (mainly due to boat discharges) of WQSs also occurred in September and October during the 10-year reporting period, resulting in closure of the clam flats by the DES Shellfish Program during these months.

Water quality relative to swimming standards

From May through September 2001, NHDES collected monthly samples for enterococci from four stations in the central part of the harbor as part of the EPA-funded National Coastal Assessment. The geomean FC concentrations for these stations was 6.2, 9.0, 4.6, and 4.3 cts/100 ml, thus showing compliance with the primary contact recreation (swimming) standard during this period.

Evaluation of bacteria loading

1. Regulated point sources

1a. Hampton WWTF

Based on Discharge Monitoring Reports (DMRs) from 1989 to 2001, NHDES calculated the geometric mean loading rate from the WWTF to be 0.3 bill FC org/day. NHDES notes that the 91% decrease in bacteria loads from the WWTF over the period 1989 to 2001 is due to a decrease in bacteria concentration rather than to decreasing flow. The current permit for this facility (2002-2006) allows a maximum monthly average FC concentration of 14 MPN/100 ml and a daily maximum FC concentration of 43 MPN/100 ml (i.e., the effluent limits have been set based on applying the bacteria criteria at “end-of-pipe.”). Taking into account the largest possible flow through this facility, the WWTF is currently

permitted to discharge a maximum of 7.7 bill org/day.

1.b. EnviroSystems, Inc. and Aquatic Research Organisms, Inc.

Each of these NPDES-permitted sources contributes a negligible amount of bacteria loading.

1c. Storm drains

NHDES identified Phase II MS4 stormwater discharges as significant sources of bacteria during and immediately following storms. To estimate the bacteria loads from these sources to the harbor, NHDES sampled 16 stormwater drains that potentially contribute significant amounts of bacteria. Stormwater maps from the Hampton Department of Public Works (DPW) show that the monitored storm drains (Hampton Beach area) channel stormwater discharge from the highly developed area (25-50 percent impervious) south of Ocean Boulevard.

Two types of storms were monitored: (1) a short, intense storm on July 23, 2002 (0.33 in rain over 4 hours), and (2) a soaking rain with high winds on October 16, 2002 (1.39 in rain over 12 hours). EPA agrees with NH's assumption that these two storms can reasonably be expected to represent the range of typical storm loadings. NHDES estimated that the FC load to the harbor during the July storm was 120 billion organisms, and during the October storm was 630 bill orgs. These results confirm that MS4 storm drains can contribute significant bacteria loads to the harbor during storms.

2. Nonpoint sources and non-NPDES point sources

NHDES also estimated loads from existing nonpoint sources and non-NPDES point sources, which, for Hampton/Seabrook Harbor, include (1) discharges from boats in mooring fields or marinas, (2) dry-weather human and wildlife sources, and (3) stormwater not conveyed through MS4 system (e.g., conveyed via tributaries and via overland runoff).

2a. Boats

NHDES conducted two field surveys on August 14 and October 17, 2002 to evaluate potential bacteria loading from boats moored or docked in the harbor. Loading from this source is from releases of untreated sewage. On August 14, all 143 slips at the Hampton River Marina were filled and about 30 boats were in each of the two mooring fields at Hampton River and Seabrook Harbor. On October 17, 52 of the slips at the Marina were filled and 15 boats were in each of the two mooring fields.

According to NHDES, US Food and Drug Administration (FDA) estimated in 2002 that 50 percent of boats in the marina discharge sewage. NHDES notes that moored boats are mainly commercial and operate out at sea; therefore, NHDES assumed that 50 percent of these boats have marine sanitation devices and that 50 percent of those with devices

discharge sewage. Therefore, the number of discharging boats ranged from 86 in August to 33 in October. Using NHDES standard procedures for estimating bacteria loads from boats, they estimated 132 to 344 billion FC orgs/day, with an average of 238 bill orgs/day for this period.

2b. Dry-weather human and wildlife/natural sources

NHDES identified possible dry-weather human sources of bacteria to the harbor as including failing septic systems and illicit discharges of wastewater to the stormwater system. (Based on a comment from EPA, NHDES subsequently acknowledged that illicit connections are regulated point source discharges rather than nonpoint discharges.) Wildlife/natural sources are mainly wastes from birds and other wild animals. NHDES used a mass-balance model to analyze contributions from these sources during dry weather. Model assumptions included assumptions that (1) the only dry-weather bacteria sources are the WWTF and other permitted facilities, boats, and wildlife and human nonpoint sources; (2) tidal flushing is the main mechanism for removing bacteria from harbor; (3) FC concentrations are relatively constant during dry weather; and (4) FC bacteria is added to harbor at a rate about equal to its removal by tidal flushing.

Based on available year-round dry-weather records from 1993-2002, NHDES estimated that the dry-weather geomean FC concentration in the harbor is about 7 MPN/100 ml. Using this estimate, the total export of bacteria by tidal flushing during dry weather is about 2021 bill org/day. Subtracting estimated loadings for the WWTF and boat discharges, NHDES estimated the dry-weather NPS loads to be 1783 bill org/day.

Because microbial source tracking showed the ratio of human to wild-animal sources to be about 60:40 (see TMDL Review Element #1), NHDES estimated the dry-weather human source load at 1070 bill org/day and the dry-weather wild-animal source load at 713 bill org/day.

2c. Stormwater loads from tributaries

Seven major tributaries drain the Hampton/Seabrook Harbor watershed. NHDES monitored each of these tributaries approximately hourly during the storms of July 23 and October 16, 2002 (see also *Stormwater loads from storm drains*). Flow was also estimated for one tributary (Mill Creek) using a stage-discharge relationship. Of all the tributaries, Mill Creek had the highest FC concentrations during both storms, which is consistent with the observation that the highest FC concentrations for the NSSP stations occurred at the mouth of Mill Creek (HH19) (see Tables 15 and Table 11 of TMDL report). NHDES estimated bacteria loading from this tributary during the two storms to be 10 to 26 bill org/day; however, they note that these loadings only include those bacteria counts during the storms and omit additional loadings (potentially higher than during storms) that occur for several days following storms from watershed runoff.

To estimate the significance of loadings from all tributaries relative to loadings from other sources, NHDES assumed loading from each of the other tributaries to be roughly equal to the loading from Mill Creek, so that the total load from all tributaries is estimated to be 68 to 179 bill org/day.

3. Total stormwater loads

As mentioned above (*Stormwater loads from storm drains* and *Stormwater loads from tributaries*), a selected number of stormwater sources (16 of over 100 MS4 sources and one of 7 tributaries) were monitored. In addition to these sources, there is also direct overland stormwater flow to the harbor from developed areas and salt marshes; it is not possible, however, to monitor these sources. Therefore, NHDES used two simple models to estimate the total stormwater load during the two storms. Model results also allowed them to estimate the fraction of the total stormwater load that was captured by monitoring. They were also able to conclude that monitored stormwater sources were only a fraction (10 percent) of the total stormwater sources, and that bacteria contributions from tributaries and overland flow in salt marshes are significant.

3a. Loads from urban stormwater sources

NHDES used a runoff model (the "Hampton Beach runoff model") to estimate the bacteria load generated from stormwater runoff from the developed area of the harbor. First, NHDES used information about the two storms (i.e., storm intensity) and stormwater drainage area (i.e., area, runoff coefficient) to estimate the volume of stormwater runoff. Next, they used data from storm drain monitoring (**i.e., average FC concentration), to estimate the total load of bacteria from the Hampton Beach area. This estimate was 65 bill organisms for the July storm and 468 bill orgs for the October storm. Therefore, monitoring captured 55 percent of the stormwater load during the July storm, and 50 percent of the load during the October storm. As NHDES notes, small storm drains and overland flow likely account for the rest of the load.**

3b. Loads from all stormwater sources

NHDES developed a "tidal flushing model" by modifying the mass-balance model used to assess dry-weather sources (See "*dry-weather human and wildlife/natural sources*"). The dry-weather model was modified by adding a term to the model to account for total stormwater loads to the harbor (from MS4 storm drains, tributaries, and overland flow). The model was solved for this added term (in billions of organisms per day) by inputting the calculated geomean FC concentrations for various sized storms (calculation described under "*Water quality relative to shellfishing standards*").

This calculation allowed NHDES to conclude that the monitored stormwater load (16 MS4 drains and one tributary) was only about 8 percent of the total stormwater load to the harbor from the July storm (0.33 in storm), and only 11 percent of the total stormwater load from the

October storm (1.39 in storm). **Estimated stormwater loads from all human and wild-animal sources are given on table 19 of the TMDL report.**

4. Comparative loads from all sources

NH's analysis shows that during dry weather, the largest sources of bacteria to the harbor are dry-weather nonpoint sources (87 percent of daily bacteria load), followed by boat discharges (13 percent of load). During wet weather (>1 in precip), the largest sources of bacteria to the harbor are the stormwater load from various stormwater sources (76 percent of daily bacteria load), followed by dry-weather nonpoint sources (21 percent of load), and boat discharges (3 percent of load). The Hampton WWTF only contributes about 0.01 percent of the total annual (dry and wet weather inclusive) bacteria load to the harbor, excluding any emergency bypasses of untreated or partially treated wastewater.

Critical Conditions

Critical conditions are defined as those periods when conditions are conducive to violations in WQSs; defining these conditions can help in identifying actions that may have to be undertaken to meet WQSs. NHDES identified critical conditions for Hampton/Seabrook Harbor as all wet-weather periods year round and dry-weather periods from June through October.

Total Maximum Daily Load

Using information available on loads from all sources (described above), NHDES calculated the existing annual bacteria load to the harbor at 1,278,515 billion organisms per year. **NHDES set the TMDL (i.e., the allowable load** of 2021 bill org/day**) for the harbor based on the average daily load that exists during dry weather conditions when WQSs (both geomean and 90th percentile FC concentrations) are generally met (**unless violated by boat discharges or emergency releases from the WWTF**).** (Revised Table 21). Overall, loading to the harbor from all sources will need to be reduced by about half to meet the TMDL target. In **addition, NHDES calculated the percent reductions in FC concentration needed to achieve the TMDL at each of the 10 NSSP stations. (Revised Table 22).**

Assessment: **EPA New England agrees that the NSSP stations are representative of water-quality conditions in the central harbor because they surround and overlay the major clam flats in this area and are between any sources and this area. NSSP stations, however, do not represent water-quality conditions in the shoreline area, and additional information and analysis would be necessary before TMDLs could be established for the near-shore areas. The TMDL report did identify some areas near stormwater drains as potential exposure pathways for primary and secondary recreational uses. No measurements of enterococci bacteria (the appropriate water-quality indicator for these uses) are available from either the waterbody or stormwater pipes. Measurements will be taken as part of the monitoring plan for this TMDL to assess this risk (see TMDL review element #8).**

EPA New England concludes that NHDES has done a good job in identifying and estimating relative bacteria contributions from all dry and wet weather sources (including point and nonpoint sources) and in identifying critical conditions. We also conclude that NHDES used a reasonable approach to establish a relationship between pollutant loading and water quality. The use of models was appropriate because of the inability to monitor diffuse sources of bacteria (from salt marshes and tributaries), and for showing relative bacteria loads from various sources.

Finally, we agree with NHDES' rationale for setting a TMDL for the central harbor, and for using dry-weather conditions as a basis for this calculation. For clarification, EPA notes that even though a dry-weather condition was used to calculate the TMDL, the TMDL for the central harbor areas applies at all times and weather conditions.

4. Load Allocations (LAs)

EPA regulations require that a TMDL include LAs, which identify the portion of the loading capacity allocated to existing and future nonpoint sources and to natural background (40 C.F.R. § 130.2(g)). Load allocations may range from reasonably accurate estimates to gross allotments (40 C.F.R. § 130.2(g)). Where it is possible to separate natural background from nonpoint sources, load allocations should be described separately for background and for nonpoint sources.

If the TMDL concludes that there are no nonpoint sources and/or natural background, or the TMDL recommends a zero load allocation, the LA must be expressed as zero. If the TMDL recommends a zero LA after considering all pollutant sources, there must be a discussion of the reasoning behind this decision, since a zero LA implies an allocation only to point sources will result in attainment of the applicable water quality standard, and all nonpoint and background sources will be removed.

Load allocations (LAs) identify the portion of the loading capacity allocated to existing and future nonpoint sources, non-NPDES point sources and natural background, and may range from reasonably accurate estimates to gross allotments. As discussed above, NHDES defined three categories of nonpoint sources (and non-NPDES point sources) to Hampton/Seabrook Harbor: dry-weather nonpoint sources, stormwater nonpoint sources, and boat discharges.

An overall LA of 1738 bill orgs/day was calculated by subtracting the Wasteload Allocation (WLA) for point sources and a 10 percent Margin of Safety (MOS) from the total allowable load. The existing nonpoint-source and non-NPDES point source loads from three source categories (1784 bill org/day from dry-weather sources, 1332 bill org/day from stormwater, and 238 bill org/day from boats) will need to be reduced by about 50 percent to achieve the target LA.

Assessment: NHDES took a reasonable approach in establishing a gross LA. In response to EPA comments, NHDES adequately explained the basis for not refining the LA based on source categories (e.g., boat discharges). NH DES has done a good job in attempting to separate natural background from human sources; this information will be useful for identifying control actions that NHDES can undertake to reduce bacteria loading to the harbor.

5. Wasteload Allocations (WLAs)

EPA regulations require that a TMDL include WLAs, which identify the portion of the loading capacity allocated to existing and future point sources (40 C.F.R. § 130.2(h)). If no point sources are present or if the TMDL recommends a zero WLA for point sources, the WLA must be expressed as zero. If the TMDL recommends a zero WLA after considering all pollutant sources, there must be a discussion of the reasoning behind this decision, since a zero WLA implies an allocation only to nonpoint sources and background will result in attainment of the applicable water quality standard, and all point sources will be removed.

In preparing the wasteload allocations, it is not necessary that each individual point source be assigned a portion of the allocation of pollutant loading capacity. When the source is a minor discharger of the pollutant of concern or if the source is contained within an aggregated general permit, an aggregated WLA can be assigned to the group of facilities. But it is necessary to allocate the loading capacity among individual point sources as necessary to meet the water quality standard.

The TMDL submittal should also discuss whether a point source is given a less stringent wasteload allocation based on an assumption that nonpoint source load reductions will occur. In such cases, the State/Tribe will need to demonstrate reasonable assurance that the nonpoint source reductions will occur within a reasonable time.

Wasteload allocations (WLAs) identify the portion of the loading capacity allocated to existing and future point sources that are subject to the NPDES permit program. As discussed above, NHDES defined two categories of point sources to Hampton/Seabrook Harbor: **facilities with individual NPDES permits (the HamptonWWTF,** Aquatic Research Organisms, Inc., and Envirosystems, Inc.), **and the stormwater discharges from MS4s (now subject to a general NPDES permit). In its revised submission NHDES also included illicit connections on the WLA side of the TMDL equation, and assigned an allocation of zero.**

Annual bacteria loads from these point sources were estimated for each of these source categories (also see TMDL Review Element #3). **NHDES calculated the maximum allowable bacteria loading from the Hampton WWTF based on the facility's NPDES permit and its largest possible flow. NHDES used recent (2002) stormwater-monitoring data and a runoff model** to estimate the bacteria load generated from stormwater runoff from the developed area of the harbor.

NHDES calculated a WLA (80 bill orgs/day) for the harbor. This WLA represents about 4 percent of the TMDL (consistent with the proportion of loads from point sources to loads from nonpoint sources shown on Table 21 of the TMDL report), and includes an allocation of 7.7 bill org/day for the Hampton WWTF, 0.024 bill org/day for Aquatic Research Organisms, Inc., and 0.007 bill org/day for Envirosystems, Inc. The remaining 72 bill org/day is allocated to MS4 stormwater discharges (with an allocation of zero for illicit connections).

Assessment: EPA New England concludes that the WLAs established in the TMDL are reasonable. To satisfy the WLAs, illicit connections will have to be eliminated, and Phase II MS4 stormwater discharges will need to reduce existing loads by slightly less than 50%.

6. Margin of Safety (MOS)

The statute and regulations require that a TMDL include a margin of safety to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality (CWA § 303(d)(1)(C), 40 C.F.R. § 130.7(c)(1)). EPA guidance explains that the MOS may be implicit, i.e., incorporated into the TMDL through conservative assumptions in the analysis, or explicit, i.e., expressed in the TMDL as loadings set aside for the MOS. If the MOS is implicit, the conservative assumptions in the analysis that account for the MOS must be described. If the MOS is explicit, the loading set aside for the MOS must be identified.

A MOS accounts for any lack of knowledge concerning the relationship between pollutant loadings and water quality. **NHDES provided an explicit MOS equal to 10 percent of the TMDL for the harbor to account for any data gaps.**

Assessment: Adequately addressed.

7. Seasonal Variation

The statute and regulations require that a TMDL be established with consideration of seasonal variations. The method chosen for including seasonal variations in the TMDL must be described (CWA § 303(d)(1)(C), 40 C.F.R. § 130.7(c)(1))

Assessment: Data from the critical periods (wet-weather periods year round and dry-weather periods from June through October) were used to estimate bacteria loads to the harbor. The total load to the harbor during dry weather was used as the TMDL because WQSs are currently only met during dry weather. Therefore, this TMDL should result in attainment of WQSs during critical conditions. Because the TMDL is set to be protective even during these critical periods, the TMDL is considered to be protective of all seasons.

8. Monitoring Plan for TMDLs Developed Under the Phased Approach

EPA's 1991 document, Guidance for Water Quality-Based Decisions: The TMDL Process (EPA 440/4-91-001), recommends a monitoring plan when a TMDL is developed under the phased approach. The guidance recommends that a TMDL developed under the phased approach also should provide assurances that nonpoint source controls will achieve expected load reductions. The phased approach is appropriate when a TMDL involves both point and nonpoint sources and the point source is given a less stringent wasteload allocation based on an assumption that nonpoint source load reductions will occur. EPA's guidance provides that a TMDL developed under the phased approach should include a monitoring plan that describes the additional data to be collected to determine if the load reductions required by the TMDL lead to attainment of water quality standards.

NHDES will use data from NSSP stations (in accordance with NSSP protocols) to assess progress towards meeting WQSs for shellfishing in the central harbor. They will also use data from four National Coastal Assessment stations (collected monthly from April through December) to assess progress toward meeting WQSs for primary and secondary contact recreation. In addition, NHDES will collect sample stormwater and near-shore waters for analysis of compliance with enterococci standards for primary and secondary contact recreation.

In some cases, NHDES plans to do monitoring before and following actions intended to reduce bacteria loads from various sources (e.g., storm drains).

Assessment: Adequately addressed. If monitoring indicates that violations of WQSs continue to occur in the central harbor areas, the TMDL will be revised accordingly.

9. Implementation Plans

On August 8, 1997, Bob Perciasepe (EPA Assistant Administrator for the Office of Water) issued a memorandum, "New Policies for Establishing and Implementing Total Maximum Daily Loads (TMDLs)," that directs Regions to work in partnership with States/Tribes to achieve nonpoint source load allocations established for 303(d)-listed waters impaired solely or primarily by nonpoint sources. To this end, the memorandum asks that Regions assist States/Tribes in developing implementation plans that include reasonable assurances that the nonpoint source load allocations established in TMDLs for waters impaired solely or primarily by nonpoint sources will in fact be achieved. The memorandum also includes a discussion of renewed focus on the public participation process and recognition of other relevant watershed management processes used in the TMDL process. Although implementation plans are not approved by EPA, they help establish the basis for EPA's approval of TMDLs.

NHDES has developed an implementation plan with the goal of removing all human sources of bacteria to the harbor. This plan includes follow-up monitoring both in the harbor and at specific sources to evaluate the effectiveness of control actions, to identify any new sources, and to do any needed risk assessments

DES plans to work with the towns of Hampton and Seabrook to develop projects to reduce bacteria loads to the harbor. A preliminary list of possible projects includes:

-Use wet-weather loading data from the TMDL study to prioritize storm drains for remedial actions.
-Identify and eliminate any illicit connections to storm drains
-Promote use of nonstructural BMPs (e.g., street sweeping, pet-waste ordinances, catch-basin stenciling)
-Assist EPA in implementing federal Phase II Stormwater regulations.
-Expand use of boat sewage-pumpout facilities
-Pursue a "no discharge area" designation for the New Hampshire coast
-Promote public education about septic-system maintenance

-Conduct a shoreline survey of Mill Creek to identify bacteria sources
-Implement recommendations of NHEP/UNH study of wastewater discharges due to runoff-induced overloading or exfiltration due to aging infrastructure
-Develop more accurate measurements of bacteria loads from tidal tributaries

Assessment: Although NHDES is not required to include an implementation plan as part of their TMDL submittal, EPA New England thinks that NHDES has done an admirable job in developing and targeting steps to achieve the TMDL.

10. Reasonable Assurances

EPA guidance calls for reasonable assurances when TMDLs are developed for waters impaired by both point and nonpoint sources. In a water impaired by both point and nonpoint sources, where a point source is given a less stringent wasteload allocation based on an assumption that nonpoint source load reductions will occur, reasonable assurance that the nonpoint source reductions will happen must be explained in order for the TMDL to be approvable. This information is necessary for EPA to determine that the load and wasteload allocations will achieve water quality standards.

In a water impaired solely by nonpoint sources, reasonable assurances that load reductions will be achieved are not required in order for a TMDL to be approvable. However, for such nonpoint source-only waters, States/Tribes are strongly encouraged to provide reasonable assurances regarding achievement of load allocations in the implementation plans described in section 9, above. As described in the August 8, 1997 Perciasepe memorandum, such reasonable assurances should be included in State/Tribe implementation plans and "may be non-regulatory, regulatory, or incentive-based, consistent with applicable laws and programs."

The individual WLAs for the three wastewater discharges are based on criteria end-of-pipe. The discharges from these sources are negligible in comparison to other sources, and the WLAs do not rely on assumptions about NPS reductions. NHDES has provided an implementation plan for reducing loads from MS4s as well as nonpoint sources, boats, and illicit connections. NHDES expects many of these measures and BMPs to be implemented on a voluntary basis. In some cases, NHDES has enforcement authority to ensure that implementation occurs.

Assessment: Adequately addressed.

11. Public Participation

EPA policy is that there must be full and meaningful public participation in the TMDL development process. Each State/Tribe must, therefore, provide for public participation consistent with its own continuing planning process and public participation requirements (40 C.F.R. § 130.7(c)(1)(ii)). In guidance, EPA has explained that final TMDLs submitted to EPA for review and approval must describe the State/Tribe's public participation process, including a summary of significant comments and the State/Tribe's responses to those comments. When

EPA establishes a TMDL, EPA regulations require EPA to publish a notice seeking public comment (40 C.F.R. § 130.7(d)(2)).

Inadequate public participation could be a basis for disapproving a TMDL; however, where EPA determines that a State/Tribe has not provided adequate public participation, EPA may defer its approval action until adequate public participation has been provided for, either by the State/Tribe or by EPA.

Assessment: NHDES worked closely with Hampton and Seabrook town officials during development of the TMDL. **TMDL was made available for public comment between June 1 and August 1, 2003 on the NHDES website. DES did not receive any public comments on the report.** EPA New England concludes that NHDES has done an adequate job of involving the public during the development of the TMDL report for Hampton/Seabrook Harbor, and has provided adequate opportunity for public comment.

Sept 30 03

Gregg R+R
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May 20, 2004

Harry T Stewart, P.E., Director
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RECEIVED
MAY 28 2004
DEPARTMENT OF
ENVIRONMENTAL SERVICES

SUBJECT: Approval of Eight Hampton/Seabrook Harbor TMDLs

Dear Mr. ~~Stewart~~: Harry

It is my pleasure to approve eight Total Maximum Daily Loads (TMDLs) for the remaining waterbody segments within and tributary to Hampton/ Seabrook Harbor known to have shellfish harvesting use impairments due to bacteria contamination. All of these waters are included on New Hampshire's 2002 303(d) list.

EPA has determined, as set forth in the enclosed review document, that the bacteria TMDLs for the Hampton/ Seabrook Harbor watershed meet the requirements of Section 303(d) of the Clean Water Act, and EPA's implementing regulations (40 CFR part 130).

I want to congratulate you and your staff for the excellent work in developing these TMDLs.

Sincerely,

Linda M. Murphy

Linda Murphy, Director
Office of Ecosystem Protection

Enclosure: EPA TMDL Review Document

cc: Paul Currier, NH DES
Gregg Comstock, NH DES
Phil Trowbridge, NHDES
Carl DeLoi, EPA
Alison Simcox, EPA